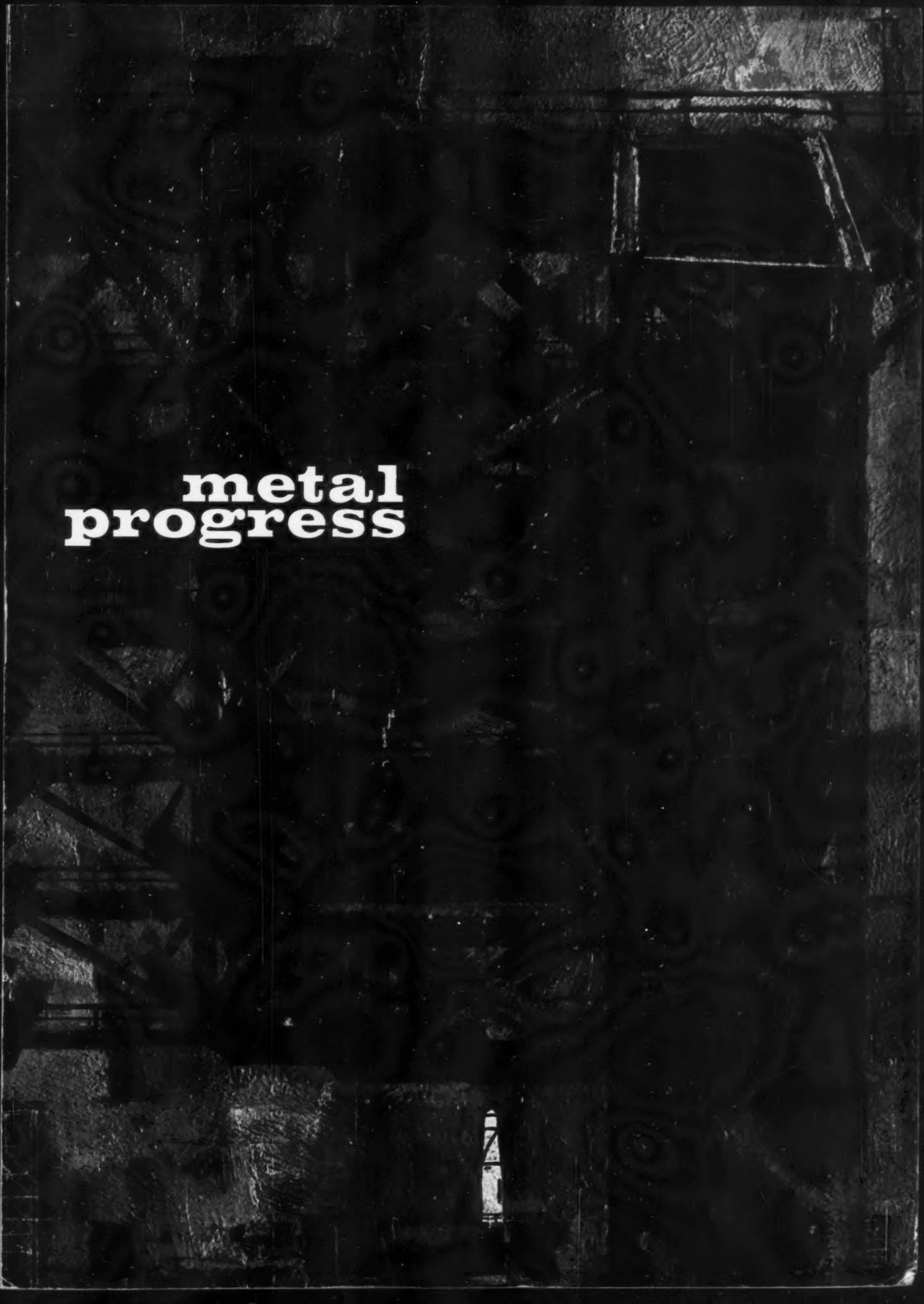
metal
progress

OPEN UP: for better drawing quality steel

The uniformity of anneal possible only through the Open Coil Process means a more uniform Rockwell with more uniform drawing quality throughout the entire coil. This enables a steel producer to duplicate orders, providing the same steel time after time, so that one stamping plant will be using precisely the same steel as another — an important consideration for decentralized manufacturing. "Stickers" are eliminated, and it is now possible to roll smoother deep-draw steels with better surface qualities for improved end products. For further information write the *Lee Wilson Engineering Co., Inc., 20005 Lake Road, Cleveland 16, Ohio.*

Circle 442 on Page 48-B

Lee Wilson

Originators and Leading Producers of Open Coil and Single Stack Furnaces

Metal Progress

July 1961 . . . Volume 80, No. 1

COVER: This month's cover, the first-prize winner in last year's *Metal Progress* Cover Contest at the Cleveland Institute of Art, was painted by ANDREW M. TOMCIK. Mr. Tomcik was the 1960 recipient of the school's $2000 Agnes Gund Award.

Table of Contents Continued on Page 3

The coding symbols on articles in Metal Progress *refer to the ASM-SLA Metallurgical Literature Classification, International (Second) Edition, 1958*

Metal Progress

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Acme Steel ACME STEEL makes 700 chemical analyses per shift with B/A Spectrometer

At Acme Steel Company, Riverdale, Illinois, a new oxygen converter makes possible highly specialized production and a forty-four-minute tap-to-tap. This high speed steelmaking method demands analysis of nine melt samples an hour—16 hours a day—seven days a week. That's why Acme relies on a Baird-Atomic Direct-Reading Spectrometer to supply quick, accurate analyses of each heat.

With just one B/A Direct-Reader, combined with carbon and sulfur analytical equipment, one Acme operator can make a complete analysis of steel (ten elements) or slag (six elements) and report back to the melt shop — in six minutes flat.

This reliable combination of: Steel by Acme-Spectroscopy by Baird-Atomic has proved itself over 10,000 steelmaking hours and more than ¾ million determinations with no standby wet-lab in the event of equipment failure.

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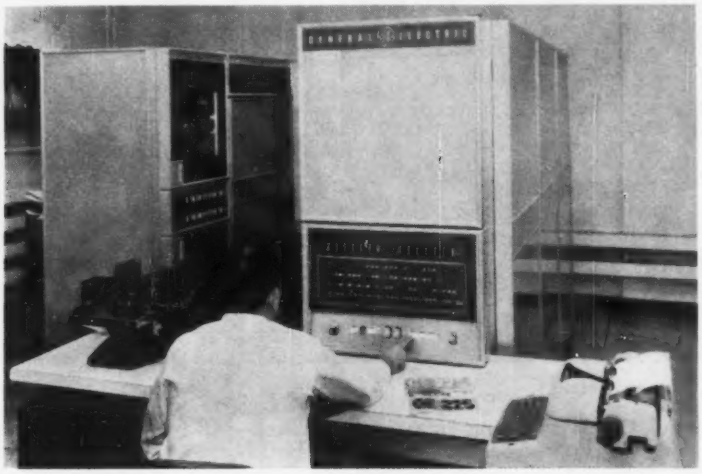
ADVANCED OPTICS AND ELECTRONICS . . . SERVING SCIENCE

Circle 524 on Page 48-B

PRESS BREAKS

Pictured on this page is an elaborate computer installed recently at Western Reserve University in Cleveland. Although known officially as a "GE 225", it can be considered as the world's first electronic librarian. Operated by the Center for Documentation and Communication Research at WRU, through the sponsorship of A.S.M. and other organizations, this unit can be programed to perform as many as 50 different literature searches at a time. In metallurgical and related literature alone, this machine has stored in its memory banks (rolls of Mylar tape) over 50,000 individual references to articles dating back to the beginning of 1958. Given the proper instructions, it will scan these tapes, and type out references for virtually any subject within the metallurgical domain.

For the readers of *Metal Progress*, most of whom are faced with tremendous problems in keeping up with fast moving develop-



The GE 225 Computer Control Console. The typewriter at right types 10 characters per sec. maximum under control of the central processor. Card reader (left) can read 400 cards per min.

ments in materials and processes (see "Are You Becoming Obsolete?", the Critical Point on p. 65), this can be an invaluable service. Instead of laboriously searching through stacks of magazines and coming up with one or possibly two pertinent articles in obscure Russian journals, the engineer can merely pick up the phone and request a literature search on the specific subject in which he is interested. In a short time, he will receive abstracts of every article published on that subject within the last three years. Or, he may subscribe to biweekly continuing searches yielding abstracts of current publications. This is a valuable supplement to the day-by-day reading the technical man must do to keep informed in his field.

As a time-saver for men in the metals field, this should be very useful. For example, a literature search might reveal that an elaborate, time-consuming research project which some company executive is considering has already been performed. As time goes on, with individual investigations steadily increasing, we look for great things from this service.

The Editors

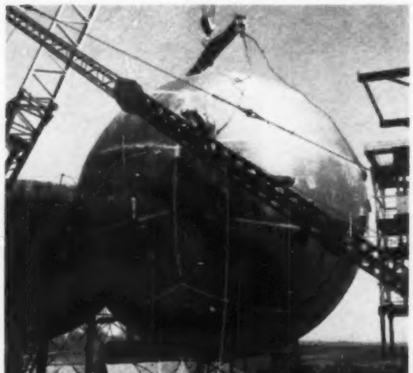
METAL PROGRESS

Technical NEWS In Brief

Huge Aluminum Vessels Store Liquid Hydrogen

Liquid hydrogen to be used as a rocket fuel at the Sacramento test facility of Douglas Aircraft Co. will be stored in two 35-ft. diameter aluminum vessels. The vessels, each of which will hold 90,000 gal. of liquid hydrogen, were made by welding sections of 5083 aluminum alloy plate, 0.835 in. thick, with 5556 alloy welding wire.

To minimize evaporation (it is expected to be held below 0.13% per day), each aluminum sphere will be enclosed in a steel tank with 60,000 lb. of expanded volcanic silicate separating the two tanks. Fabricated by Chicago Bridge & Iron Co., the storage vessels are part of a $2-million program that will permit Douglas to perform system and static tests on the Saturn S-IV vehicle, the second stage of the Saturn C-1 space vehicle.



ALUMINUM VESSEL FOR LIQUID HYDROGEN
Fabricated of 5083 Alloy, It Will Hold 90,000 Gal. of Rocket Fuel

New Vacuum Process for Heat Treating Tool Steels

Vacuum processing, which has been called on to solve some of the difficult problems in the metalworking and producing industries, is now being used to eliminate or at least minimize distortion and decarburization of high speed tool steels. By modifying the design of an existing vacuum unit, engineers at Ipsen Industries, Inc. in Rockford, Ill., have come up with a furnace for rapid heat treating of high speed steels. Once charged, the new furnace is automatic in operation; the operator merely presets the time at the intermediate soaking and final heat treating temperature. All sequences – pump down, heating and quenching (in an inert gas) are done according to the preset program.

Because heat treating is done in a vacuum (about 5 to 10 microns), there is little or no decarburization. In fact, the high temperature and low pressures involved will cause most of the surface scale to dissociate so that parts come out clean. No special precleaning step is needed. Pump down from atmospheric to operating pressure takes 5 to 10 min. and is not greatly affected by contaminants such as oil on the parts. Because the parts are heat treated in a vacuum, their sharp edges are not rounded off. The load is supported on ceramic rollers and there is little or no

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Technical NEWS In Brief

distortion. Thus, parts can often be finish-machined before heat treatment.

Another interesting feature is the speed of the vacuum unit. In treating typical parts, heating begins during pump down when the pressure reaches 50 microns. It takes about 5 min. to heat to 1550° F., the soaking temperature, and an equally short time to reach 2300° F., the final holding temperature. Quenching is done in nitrogen, and, because of effective circulation by a fan equipped with ceramic blades that blasts the gas through the load, the quench rate approximates that of a salt bath. The shortest cycle from cold part to cold part has been about 38 min.

Stress-Corrosion Immunity for 7075 Aluminum Alloy

Tests have revealed that parts of 7075 aluminum alloy in the T 73 condition, a treatment developed by Alcoa engineers at New Kensington, Pa., exhibit improved resistance to stress-corrosion cracking compared with similar parts aged to T 6 temper. When 18 items in the latter condition were tested by alternate immersion in synthetic sea water, ten of them failed in less than 1584 hr., seven of these in less than 400 hr. However, the seven parts tested in the T 73 temper under the same conditions have accumulated more than 1750 hr. without failure.

The tests, performed by engineers at Douglas Aircraft Co., El Segundo, Calif., utilized rudder hinge fittings rigged to simulate installation with bolts overtorqued by at least 120 in-lb.

Although 7075-T 73 is not as strong as 7075-T 6 (strength is about 9000 psi. lower), its use may solve a long-time problem with the high-strength alloy, particularly in naval aircraft exposed to marine atmospheres

Vapor-Cooled Resistance Welder Speeds Pipe Production

About 70% of the steel tubing and pipe made in the United States is produced by welding. Much of this is made with low frequency resistance welders. A new "Type V" welder developed by Yoder Co., Cleveland, promises to increase pipe production as much as 60% with the same power input or to maintain production levels with greatly reduced power requirements.

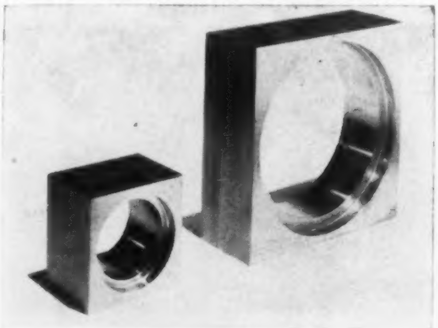
The improvement is based on a new vapor-cooled toroidal transformer which increases the current delivered to the tube being welded and decreases power input requirements. A nontoxic hydrocarbon is employed for cooling rather than recirculated water or oil. This, together with a compact design, has eliminated the secondary conductor system, thereby greatly reducing the secondary impedence and permitting the current to be transmitted directly from transformer to electrode.

On a new "Type V" unit, 12-gage steel tubing, formerly produced at 50 ft. per min. with conventional welders, is being manufactured at 80 ft. per min. Fourteen gage, formerly produced at 85 ft. per min., is now being made at 160 ft. per min. with smaller power input. A manufacturer of automobile and truck tailpipes is welding 2-in. tubes of cold-rolled and aluminized steel, 0.075 in. thick at 106 ft. per min. The welder produces 6000 pieces of 69½-in. aluminized steel sections in an 8-hr. shift with two operations.

Powder Technique Produces Dense Zircaloy-2 Parts

Zircaloy-2 is now being produced by a powder metallurgy process, a modified vacuum hot-pressing technique. According to engineers at the Metallurgical Products Dept., General Electric Co., Detroit, compacts having a density of 6.57 g. per cc., 100% of theoretical, and a microstructure which reveals no porosity can be made.

One of the advantages of the technique is that it can be used to produce finished or semifinished shapes which require a minimum of machining (see photo). This is true for refractory metal powders and their carbides as well as for Zircaloy-2. Thus, one can expect to reduce fabrication costs by decreasing necessary machining time and reducing metal losses incurred as machining scrap. Holes



PRECISION PARTS MADE OF ZIRCALOY-2 POWDER
Hot Pressed in a Vacuum, the Parts Are Free From Porosity

can also be formed directly in billets for making extruded tubing. This eliminates the need for drilling or piercing.

In addition, G. E. engineers say that properties of the compacts are nondirectional, that dispersion hardening is possible, and that the new technique can be used to effect diffusion bonds between dissimilar metals.

Hot-Dipped Aluminum Coats Steel Fasteners

In a new process now in the pilot-plant stage steel nails and fasteners are being coated with aluminum by hot dipping. The method prevents formation of brittle iron-aluminum compounds because another metal, such as chromium, is chemically deposited on the nails before they are coated with aluminum. Any of a large number of metals can be used for this buffer plate. The essential requirement is relatively low solubility or chemical reactivity in aluminum at dipping temperatures.

In the process, which was developed by Boller Development Corp., Marion, Ind., the steel is first cleaned in an alkaline solution and pickled in a hydrochloric-acid bath. A dip in an aqueous chloride solution follows, and when dried, the fasteners are chemically plated in a fused metal-chloride bath at about 1100° F. Salt adhering to the work from the plating bath is washed off in 1 to 2 sec. in a second fused salt bath maintained at 1200° F. Any dissolved heavy metals from the plating bath are precipitated in the wash bath by metallic magnesium. The washed work is then dipped through a top flux into the molten aluminum at about 1300° F. for 1 to 5 sec. Excess aluminum is removed by centrifuging, and as soon as coating has solidified, the work is quenched in dilute nitric acid. Thickness of the coating may be varied between about 1 and 2 mils and is controlled by the temperature of the aluminum bath and intensity of centrifuging. An optional step is chemical polishing in a conventional nitric-phosphoric acid bath.

The coating is characterized by smoothness, uniformity over irregularities such as threads, and its capacity for deformation without flaking or peeling. Its appearance and corrosion resistance are those of the aluminum alloy used.

Automatic Welding Gun Makes Leak-Proof Welds

Described in *Metal Progress* for July 1960 (p. 131) was an automatic welding gun designed primarily for welding tubes to tube sheets for condensers. The gun employs a rotating shielded tungsten electrode which rotates to follow the joint as it makes the weld. A special joint design precludes the need for filler wire and strong pressure-tight joints are made. Designed by engineers at Revere Copper and Brass, Inc., New York, the gun has proved valuable in welding 30 tons of cupronickel tubes and tube sheets in the main and auxiliary condenser units of the N.S. Savannah, our first atomic-powered merchant ship.

WELDING GUN JOINS TUBES TO TUBE SHEETS
Gas-Shielded Tungsten Electrode Rotates Along the Joints and Makes Strong, Leak-Proof Welds

Now it is being employed in a similar manner to join tubes to tube sheets in the steam condensers (see photo) of a new nuclear power station being built now at Indian Point, N.Y., for Consolidated Edison Co. Chosen primarily because of past performance in producing leak-proof welds, its reliability and convenience of operation are attractive points since the condenser includes 31,508 tubes.

Japanese Report Properties of L-D Steels

Though steels made in basic oxygen converters have been used more and more in this country within the last few years, surprisingly little is known about their actual properties. Recently, it was learned (through an article appearing in *Tetsu To Hangané*, Vol. 46, No. 10, 1960) that engineers of the Yawata Iron and Steel Works have compiled facts and figures comparing compositions, mechanical properties, and surface qualities of low-carbon, rimmed steels made in L-D units (88 heats) and in open hearths (66 heats).

As reported in Brutcher Translation No. 5072, phosphorus, sulfur, and nitrogen contents of the L-D heats averaged 0.017, 0.018 and 0.017%, respectively. In general, mechanical properties were

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Technical NEWS In Brief

lower than those of the comparable open-hearth heats, but ductility, workability, and surface quality were better. Such improvements were attributed to the smaller amount of impurities and nonmetallic inclusions in the L-D steels. It appears from these results that much can be expected from oxygen-converter steels for deep drawing. Apparently, the use of greater amounts of hot metal and "home" scrap only for these heats accounts for the lower gas, impurity and nonmetallic inclusion contents.

Progress in Nonmetallic Materials

Extensive testing has demonstrated that a new family of ceramic composites will provide corrosion resistance to metals at high operating temperatures. The composites, known as Nucerite (see *Metal Progress, November* 1960, p. 68), are applied as coatings over metal components. They will resist corrosive attack up to 1600° F. (see photo).

According to engineers of Pfaudler Co., Rochester, N.Y., a division of Pfaudler Permutit Inc., the coatings have held up when exposed to such corrosive media as metal halides at 1290° F., refractory metal chlorides at 600° F. and aqua regia containing abrasives at 225° F.

• • •

Shown at the recent Design Engineering Show in Detroit were leaf, coil and torsion springs made of Mylar, a polyester film. Although these plastic springs are not functional much above 175° F., they retain a higher flex life than most metals down to about –75° F. The nonmetallic devices exhibit such properties as extendability, retractability and constant tension. Engineers at DuPont's Film Dept. which produces Mylar, say that springs made of the plastic might be used in door and window closures, room dividers, toothed drive shafts, shock-absorbing straps and temperature-moisture sensing devices.

Ceramic Coating Protects Bayonet Heater
It Prevents Corrosion at High Temperatures

From Here and There

Spent nickel anodes representing 10 to 20% of the weight of the original anodes used in nickel-plating systems can be loaded into titanium baskets and used entirely. The baskets, (available from Gamble and Gamble, Buffalo, N.Y.) will pass current to the nickel scrap but not to the bath. Because of the excellent corrosion resistance of titanium in a nickel plating bath, the life of the baskets is estimated to be at least ten years.

• • •

A superconductor alloy capable of carrying 100,000 amp. per sq.cm. in a magnetic field of 30,000 gauss has been developed by Atomics International, Canoga Park, Calif., a division of North American Aviation, Inc. The alloy contains about three parts columbium and one part zirconium and is used in the cold worked condition. It has potential applications in superconducting magnets for high-energy particle accelerators, controlled thermonuclear research devices and where light weight is essential. Such magnets would store more electrical energy in less space than conventional electrical capacitors.

• • •

An unusual decorative finish can be obtained by electroplating textured metal surfaces and then buffing the coating from raised areas. The technique, introduced recently by Metal & Thermit Corp., N.Y., produces a variety of effects depending on the basis metal, its texture, and the electroplate. An example is to plate a textured steel with zinc, apply a conversion coating, dye it, and then buff it to bring out the bright zinc.

Forming Parts by High-Energy Techniques

High-energy forming has progressed in recent years from the status of an interesting, perhaps spectacular, technique to a true production process. It can shape difficult-to-work metals and large, complex parts and do so with precision. The advantages will be discussed in *Metal Progress* next month in a special report which will give designers a better idea of where high-energy forming can be used and what can be expected of it.

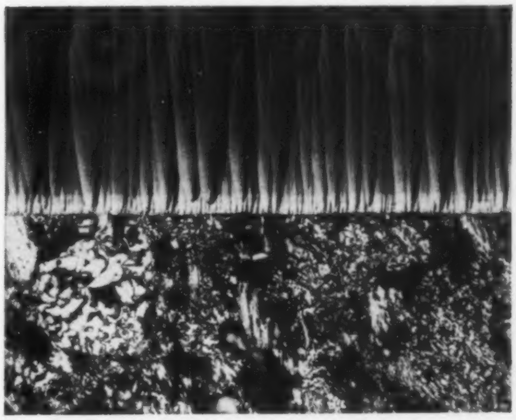
Pyrolytic Graphite*

What it is . . .
What it does . . .
What it can do

* Pyrolytic Graphite—now commercially available—is a polycrystalline form of carbon produced by gas deposition. It exhibits a metallic behavior (high conductivity) in the planes of deposition, and a ceramic behavior (low conductivity) across the planes.

Some of its unique properties include: high strength at high temperatures up to 5000°F.; impermeability to gases and liquids; excellent thermal and electrical conductivity parallel to the plane with insulating characteristics across it; is very lightweight.

Produced as a coating on commercial graphite, it can also be built up to sufficient thickness for use as free-standing parts. Pyrolytic Graphite is well suited for many space, missile and electronic applications, including leading edges, rocket nozzles, and coatings for nose cones.



Note structural differences between ordinary graphite (bottom) and Pyrolytic Graphite (top). Ordinary graphite has crystals arranged at random with high porosity; pyrolytic crystals have high degree of orientation with no porosity.

For additional information, write: *Specialty Alloys Section, Metallurgical Products Department of General Electric Company, 11113 E. 8 Mile Road, Detroit 32, Michigan.*

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Circle 527 on Page 48-B

METALGRAMS

UNION CARBIDE METALS

. . . news of "Electromet" ferroalloys and metals

JULY 1961

MAKING MORE PERFECT METALS -- Vacuum melting is meeting the higher property requirements of space and atomic uses. This young, growing industry is producing steels and superalloys with better properties than those melted in air. These vacuum-melted alloys have better ductility, impact strength, fatigue strength, and rupture and magnetic properties. Vacuum melters are also making superalloys and ultra-pure metals that cannot be melted in air. These metals and alloys have produced impressive results. Ball-bearing life has doubled. Jet engines operate longer at higher temperatures. Nuclear reactors can run efficiently.

* * *

ALLOYS FOR VACUUM MELTING -- Union Carbide Metals supplies a complete range of ferroalloys and metals for steels and superalloys melted by both major vacuum-melting processes. In vacuum-arc melting, an air-melted electrode is remelted to improve purity and uniformity. Ferroalloys must be added during air melting since vacuum-arc melting does not allow alloy adjustments. In vacuum-induction melting, alloy additions are made in the vacuum furnace. Metals such as "Elchrome" electrolytic chromium and "Elmang" electrolytic manganese are desired for such additions because of their purity. For more information, call your Union Carbide Metals representative today. Also, ask for the article, "Making More Perfect Metals," in the Summer 1961 issue of UNION CARBIDE METALS REVIEW.

For more information circle 521 on page 48-B

* * *

ULTRA-PURE METALS, TOO -- UCM also offers ingots of columbium, tantalum, and vanadium metal made by a new vacuum process -- electron-beam melting. The electron-beam process provides the purity needed to make these metals ductile and easily formable. All three metals have one property of wide interest to metallurgists -- high strength at elevated temperatures. Thus, they may be the key to future hypersonic flight vehicles. The three metals also resist corrosion. In fact, tantalum chemical equipment resists both oxidizing and reducing media better than most other materials. Columbium effectively resists molten salts. Other properties: columbium and vanadium have moderate neutron cross-sections, allowing use in nuclear reactor structures. Tantalum has ideal dielectric properties for electronic capacitors. Your UCM representative can give you further information and literature on each of these metals.

For more information circle 522 on page 48-B

* * *

UNIQUE VACUUM PROCESS...BETTER ALLOY ADDITIONS -- In the world's largest vacuum furnaces at Marietta, Ohio, UCM eliminates certain hard-to-remove elements from ferroalloys and metals. They aren't removed by melting. They are removed by refining in the solid state. For example, carbon is virtually eliminated from "Simplex" ferrochrome, allowing carbon-free additions to stainless steel. Gases are removed from "Elchrome" VG chromium metal. Thus, less gas is evolved when the metal is used in vacuum-induction melting. Also, nitrogen is added to certain chromium and manganese alloys...for convenient nitrogen additions to stainless steel. Learn more about this unique vacuum process by writing for the article, "The Silent World of SIMPLEX," in the Summer 1960 issue of UNION CARBIDE METALS REVIEW.

For more information circle 523 on page 48-B

* * *

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features improved physicals, closer tolerances, better finish

Circle 529 on Page 48

Circle 530 on Page 48-B


Milk
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Linde *Coatings & materials* News

LINDE COMPANY, DIVISION OF UNION CARBIDE CORPORATION

Surgical shears get longer life with LINDE tungsten carbide coating

Surgical shears with tungsten carbide coated on working surfaces now lose their cutting edge about *one-third* as fast as conventional shears. This has been proven under rigid testing supervised by a leading research laboratory.

The American Medical Instrument Corporation, Flushing, New York, uses the LINDE Flame-Plating process to improve the working surface and increase the wear-resistance properties of shears produced under its *Tuncarb* trade-mark.

The process has increased cutting life to the extent that *Tuncarb* shears in use for more than a year have not as yet been returned to AMICO for sharpening. By comparison, regular surgical shears used under the same conditions had to be returned as many as three times for restoration of working surfaces.

Coatings only .004″ thick

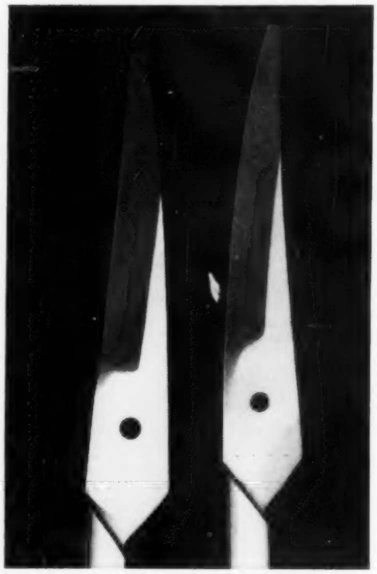
AMICO ships hot-drop-forged stainless steel parts to LINDE's new Flame-Plating plant at North Haven, Conn. Here, via the LINDE developed coating process, a .004″ thickness of tungsten carbide is actually "welded" to the precision wear surfaces of the instruments.

After coating, the blades and jaws are assembled, riveted, ground, polished, and buffed to a high finish by AMICO. The tungsten carbide surfaces themselves are finished with only a slight brushing. The same process is used to coat *Tuncarb* needle holders to provide tungsten jaws that give a firm grip on needles.

High-speed "blast-on"

The heart of LINDE's coating process is the LINDE Flame-Plating gun, into which exact quantities of oxygen, acetylene, and tungsten carbide or other powdered materials are fed by a special mechanism. After the gun is aimed at the area to be coated, controlled detonations "blast" the particles onto the work piece at speeds up to 2500 fps—until the desired coating thickness is reached.

Although temperatures of about 6000° F are attained within the detonation gun to heat powder to plastic state, the work piece itself is always kept below 400° F during the operation. There are no changes in the properties of the base metal and no distortion of the work piece regardless of its minuteness.



The inside cutting surface of the *Tuncarb* surgical shears shown here have been coated with tungsten carbide, reducing their rate of wear by as much as one-third.

In some uses, depending on the thickness of finish, the LINDE Flame-Plating process has been known to multiply wear resistance of metal parts by as much as 40 times.

For complete information on how you might use this advanced method of coating metals to improve production or reduce operating costs, check and send the coupon below.

LINDE synthetic sapphire solves guide problem in tape recorders

Second only to the diamond in hardness, LINDE synthetic sapphire provides unique wear-resisting characteristics. Because of its extremely low friction, hardness, and physical and chemical stability, several large manufacturers are using LINDE synthetic sapphire to solve the wear problem in tape guides on airborne and high-reliability tape decks, as well as in photographic film guides.

In these areas—where hardened steel guides show friction and wear almost immediately—sapphire wear is nearly imperceptible even after 100 hours of operation.

LINDE flame-polished synthetic sapphire is a convenient material for preventing edge-cutting typical with certain tapes in top and bottom guides.

For details on LINDE synthetic sapphire for any type of wear guide, instrument bearing, or other critical application, check and mail the coupon.

Chromium polished to maximum lustre with LINDE abrasives

In certain applications where it is necessary to achieve an extremely smooth surface on chromium finishes, such as in photographic rolls and processing rolls in the plastics industry, LINDE alumina abrasive powders of 99.98% purity have demonstrated unusual efficiency in removing the most minute protuberances.

Several leading photographic and precision parts manufacturers use LINDE abrasives, not only to obtain high-lustre finishes that protect materials, but also to refinish rolls several times over to avoid frequent replating.

Grades of LINDE alumina powders in sub-micron sizes are available for several cutting speeds or types of finish. For information, use the coupon below.

CHECK—CLIP COUPON—ATTACH TO BUSINESS LETTERHEAD

Linde Company, Dept. MP-7
270 Park Avenue
New York 17, N.Y.

Please send details on the items checked:

☐ LINDE Flame-Plating
☐ LINDE Synthetic Sapphire
☐ LINDE Alumina Abrasives

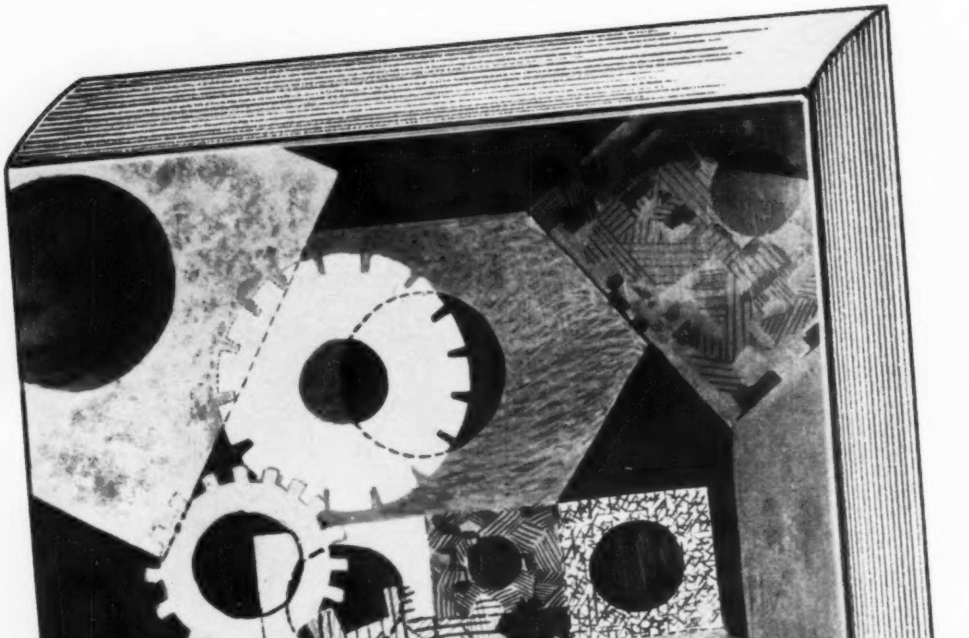
UNION CARBIDE

LINDE COMPANY

"Linde" and "Union Carbide" are registered trademarks of Union Carbide Corporation

Circle 495 on Page 48-B

Announcing . . .
an outstanding issue

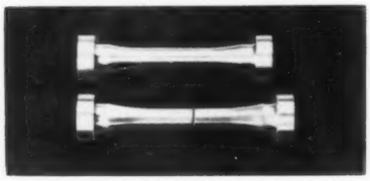


NEW PRODUCTS

Materials

Heavy Tungsten Alloy

Applications for "Kennertium", a tungsten alloy which is 50% heavier than lead, include radioactive shielding, counterweights and high-inertia



rotational parts that require maximum weight in minimum space. Compressive strength is 500,000 psi., tensile strength is 135,000 psi., and elongation ranges from 10 to 25%. This nonmagnetic alloy has a yield point in compression of 85,000 psi., a Brinell hardness of 270 to 297, and a modulus of elasticity of 45,000,000 psi. Kennertium has a coefficient of thermal expansion of 3.7×10^{-6} in. per in. per ^{o} F. in the range 100 to 1200^{o} F. *Kennametal Inc.*

For further information circle No. 200 on literature request card, p. 48-B

Tooling

350,000 Psi. Tool Steel

Designed for tools and dies that require resistance to extreme shock, "Hi Shock 60" retains ductility and toughness up to strengths of 350,000 psi. Heat treated to a hardness of Rockwell C-59, the steel has an unnotched Charpy impact strength of 110 ft-lb. Containing 0.68 C, 0.50 Mn, 0.30 Si., 1.00 Cr, 0.50 Ni, 1.00 Mo, 2.50 Cu, and 0.15 V, the steel has a low hardening temperature of 1600^{o} F. and is tempered at 300 to 400^{o} F. to obtain the best combination of hardness and toughness. Applications include hobs, heavy-duty punches, mandrels, gun barrels and other tools subject to high shock. *Carpenter Steel Co.*

For further information circle No. 201 on literature request card, p. 48-B

Strip-Forming Machine

The "V-80" vertical four-slide machine is designed for high-speed production of small wire and strip components. This precision unit can be adapted to add welding, tapping, swaging, thread-rolling, and other secondary operations automatically

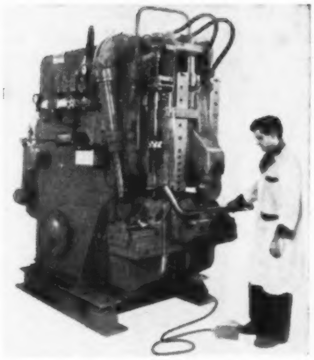
within or parallel to the primary forming cycle. Stock capacity is ¾ in. wide by 0.032 in. strip thickness, or 1/16 in. wire diameter. Production rates are from 100 to 500 strokes per min., depending on feed length and product. *Torrington Mfg. Co.*

For further information circle No. 202 on literature request card, p. 48-B

40-Ton Bending Press

The "Model 40T" bending press increases output and reduces production bending costs on tube and pipe in sizes up to 4 in. diameter. This 40-

Circle 497 on Page 48-B



ton machine produces smooth, good quality bends at production speeds 3 to 4 times faster – up to 800 bends an hour – than conventional bending methods. It can apply sufficient force to handle laminated tubing (one tube inside another) or heavy-wall boiler tubing. *Pines Engineering Co.*

For further information circle No. 203 on literature request card, p. 48-B

Semi-Automatic Forging

The "Ceco-Drop" gravity-drop hammer, which replaces the traditional board-drop hammer, is easier and safer to operate and costs less to maintain. The hammer eliminates down-time to change or adjust boards, and the cost of rollers, pulleys, motors, gears and boards. The "Blowmatic" program controller converts the Ceco-Drop into a semi-automatic installation by presetting the optimum blow pattern sequence for a particular forging. *Chambersburg Engineering Co.*

For further information circle No. 204

Heating

Spiral-Flame Burner Increases Furnace Capacity

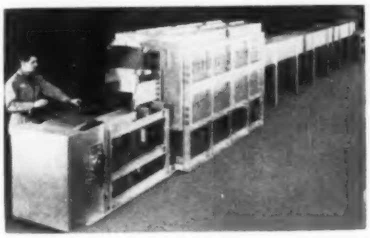
This burner from *Eclipse Fuel Engineering Co.* creates a flat, spiral flame which hugs the arch or walls of heat treat furnaces or galvanizing tanks. The flame-scrubbing action increases over-all heat transfer rates. Work can be located close to the

burner without creating hot spots. Equipped with the "Star-Sixties" burner, new furnaces can be smaller with lower heat losses; or present furnaces can handle larger loads. Six burner sizes give capacities from 100,000 to 1,800,000 Btu. per hr. Flame diameters range from 13 to 60 in.

For further information circle No. 205

Mesh-Belt Furnace

Harper Electric Furnace Corp. has introduced a straight-through mesh-belt furnace which maintains a pure atmosphere in continuous brazing, annealing, and sintering operations. A variable-speed drive allows processing of a wide variety of metals of



different thicknesses and cycle requirements. Work can be placed directly on the belt, or in baskets or other carriers. All gas-fired models are equipped with muffles; electric models with nichrome or silicon carbide elements can be furnished with or without muffles.

For further information circle No. 206

5000° F. Graphite Furnace

A vertical furnace that will produce temperatures to 5000° F. has been added to *Lindberg Engineering Co.'s* equipment line. The graphite element is 5 in. I.D. by 18 in. high with a 6 in. effective work height which can be controlled within ±25° F. The bottom-loading graphite hearth, 4½ in. O.D., is raised and lowered

KNOW YOUR ALLOY STEELS . . .

This is one of a series of advertisements dealing with basic facts about alloy steels. Though much of the information is elementary, we believe it will be of interest to many who may find it useful to review fundamentals from time to time.

for Strength
. . . Economy
. . . Versatility

Determining the Proper Depth of Case in Alloy Steels

In one of the recent articles in this series we discussed the carburizing of alloy steels, pointing out that the purpose of carburizing is to provide a hard, abrasion-resistant outer shell or "case." Such a discussion naturally gives rise to the question, What factors influence the choice of case? Should it be shallow? Medium? Deep or extra-deep?

While it is not always wise to formulate hard-and-fast rules, the following may be used as a general yardstick:

Shallow cases (less than 0.02 in.). Suitable where wear-resistance alone is the chief requirement, and where good surface condition after heat-treating is advantageous. Not suitable if high stresses are apt to be encountered in service.

Medium cases (0.02 to 0.04 in.). For high wear-resistance. Will stand up under substantial service loads and stresses. The thickness is sufficient to permit certain finishing operations, such as light grinding.

Medium-to-deep cases (0.04 to 0.06 in.). For high wear-resistance. A case in this depth range is essential where continuing friction is involved, especially friction of an abrasive or semi-abrasive nature. It is also a good precautionary measure where application of the finished part may sometimes involve crushing action.

Extra-deep cases (more than 0.06 in.). Cases of this depth can be obtained by extending the furnace time in pack carburizing. Highly wear-resistant, extra-deep cases also withstand shock and impact. A large camshaft of an internal-combustion engine is a good example of a part requiring the extra-deep case. This is especially true of the cam lobes themselves.

If you need advice concerning case-hardened parts, let us arrange for one of our metallurgists to assist you. Bethlehem engineers are always on call, and you can depend on their recommendations. And you can depend on Bethlehem, too, when you need alloy steels; for Bethlehem makes the full range of AISI standard grades, as well as special-analysis steels and all carbon grades.

This series of alloy steel advertisements is now available as a compact booklet, "Quick Facts about Alloy Steels." If you would like a free copy, please address your request to Publications Department, Bethlehem Steel Company, Bethlehem, Pa.

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA. *Export Sales:* Bethlehem Steel Export Corporation

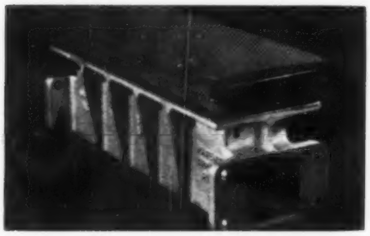
BETHLEHEM STEEL

Circle 499 on Page 48-B

with a handwheel. The "Type TRV-25-518" furnace is ideally suited to uses such as firing of pyrolytic graphite, experimental studies of high-temperature reactions, or compression studies at high temperatures.

For further information circle No. 207 on literature request card, p. 48-B

Gas-Fired Infrared Burner

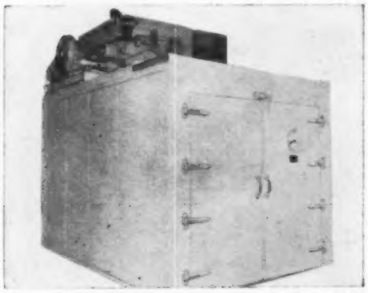


A bottom inlet on this gas-fired burner serves to eliminate complex distribution manifolds in continuous lines (up to 200 ft. long) or radiant panels of any shape required. A single pilot will light the entire assembly and only one flame-sensing device is needed per panel. Heat input is 20,000 Btu. per hr. per ft. of length. Face temperatures range from 1200 to 1800° F. Suggested uses are curing shell molds and cores, baking paint and enamel, and drying applications. *Bryant Industrial Products Corp.*

For further information circle No. 208

Walk-In Production Ovens

Rated at 850° F. maximum, these gas, oil, or electrically heated ovens are available in six models from 250,000 to 1,500,000 Btu. per hr. The "Super Duty S-Type" ovens – with interior dimensions ranging from 4 ft. 6 in. by 6 ft. by 6 ft. to 8 ft. by 12 ft. by 6 ft. 9 in. – have an approved safety system and indicating-type controllers. *Despatch Oven Co.*



For further information circle No. 209

Thermostats for Special Environments

"Type GP" thermostats – useful where moisture, fumes or dust is a problem – contain a bimetallic disc element in close proximity to an aluminum sensor cap, to provide rapid response to temperature changes. Enclosed in a polypropylene boot filled with epoxy resin, the instantaneous, positive action of the unit prolongs life by minimizing arcing and eliminating chattering and false cycling. Typical ranges are −20 to 79° F. and 80 to 176° F. in applications such as pilot duty and temperature protection in liquid coolers, freezers and industrial apparatus. *Stevens Mfg. Co., Inc.*

For further information circle No. 210

Finishing

Nylon Polishing Belt

An abrasive belt that outlasts other coated polishing belts (up to 40 times as long) and produces a micro-finish never before possible has been introduced by *Armour Alliance Industries.* The product is heat and water resistant, does not load up readily, and reduces changeover time. The nylon belts are available with aluminum oxide or silicon carbide abrasive grain sizes from coarse to superfine, and in widths (up to 24 in.) and lengths to fit any belt-sanding machine.

For further information circle No. 211 on literature request card, p. 48-B

Polishing and Deburring Machine

Three-dimensional, high-frequency, low-amplitude vibration is utilized in a "Vibro-Energy" finishing mill to polish and deburr metal, plastic and ceramic parts. A spiral, orbital movement of the parts through the media and compound – plus the vibrating and sliding action associated with barrel finishing – imparts a gentle action especially suited for processing fragile parts. The technique lowers production costs by shortening the time cycle and at the same time improves product finish. A quick-opening discharge door provides fast unloading. *Southwest Engineering Co.*

For further information circle No. 212 on literature request card, p. 48-B

Plating Process for Aluminum

A zincating bath for plating on aluminum uses only 1 lb. of "Alumon D" salts per gal. versus 4 or 5 lb. per gal. in a conventional zincate bath. It is easier to make up, is freer rinsing, penetrates readily into grooves and screw threads, and minimizes carry-over into subsequent baths. The amount of salts lost through dragout is 1/12 that lost from conventional baths. Used after cleaning and acid dipping, an Alumon D bath activates the aluminum and deposits a thin, uniform zinc film, which is then electroplated with copper or nickel. Immersion times in the solution vary from 15 sec. to 2 min. at room temperature. *Enthone, Inc.*

For further information circle No. 213

Welding

Two Cuts With One Torch

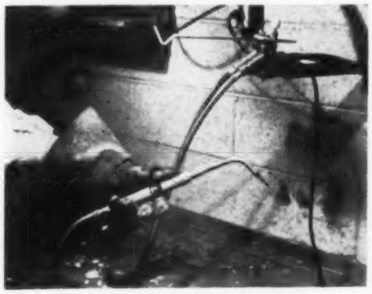
The *Harris Calorific Co.* is introducing an "Adjustable Twin Tip" holder that makes possible two simultaneous cuts (within a spread of 1½ to 12 in.) from one machine-cutting

torch. Particularly applicable to sheet and plate strip cutting, the "Model TH-98" will operate on any gas and provides complete safety in any position because of the "O"-ring seals at the pivot point.

For further information circle No. 214

Torch for Continuous Welding

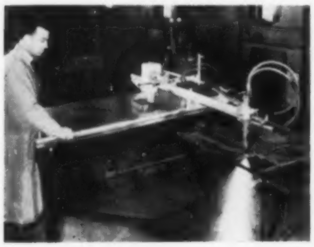
Greater economy in gas consumption and reduced operator fatigue in



production welding and brazing operations is claimed for the "Model 725" lightweight valveless torch. The unit differs from standard dual-hose torches in that needle valves have been eliminated. A "gas-mizer" located at the regulators controls flame adjustment and shuts off the fuel mixture when the torch is hung up. Rugged, dependable, with increased gas capacity, the equipment can handle practically all production welding and brazing jobs. *Air Reduction Co.*
For further information circle No. 215

Metal-Cutting Machine

The "Type RM1" portable oxy-acetylene cutting unit designed for small workshops can be operated safely by unskilled labor. The lightweight equipment, easily moved and quickly set up, will make longitudinal or transverse cuts of up to 50 in. and



30 in., respectively, and will produce circles with radii from 2⅜ to 15¾ in. Accurate results are obtained in automatic cutting employing steel templates, in square or bevel-edge straight-line cutting, in hand-guided cutting, and in compass-guided circular cutting. *National Cylinder Gas.*
For further information circle No. 216 on literature request card, p. 48-B

Testing

Elevated-Temperature Testing

An integrated test unit for evaluating materials under extreme conditions of stress and temperature is capable of simulating actual service. Load and strain are controllable over a wide range; specimens can be heated slowly or in seconds; and the

combined effects of rapid heating and loading, constant loads, and cyclic loads can be determined. Load capacity is 50,000 lb.; loading rate ranges from 0 to 50,000 lb. per sec. Heating rate is variable up to 250° F. per sec.; maximum temperature is 5000° F. Cycling: 0 to 10 cps. (tension-tension or compression-compression); bias level and cycle amplitude are both continuously variable. *Marquardt Corp.*
For further information circle No. 217 on literature request card, p. 48-B

Mixing Concentrates for Magnetic Particle Testing

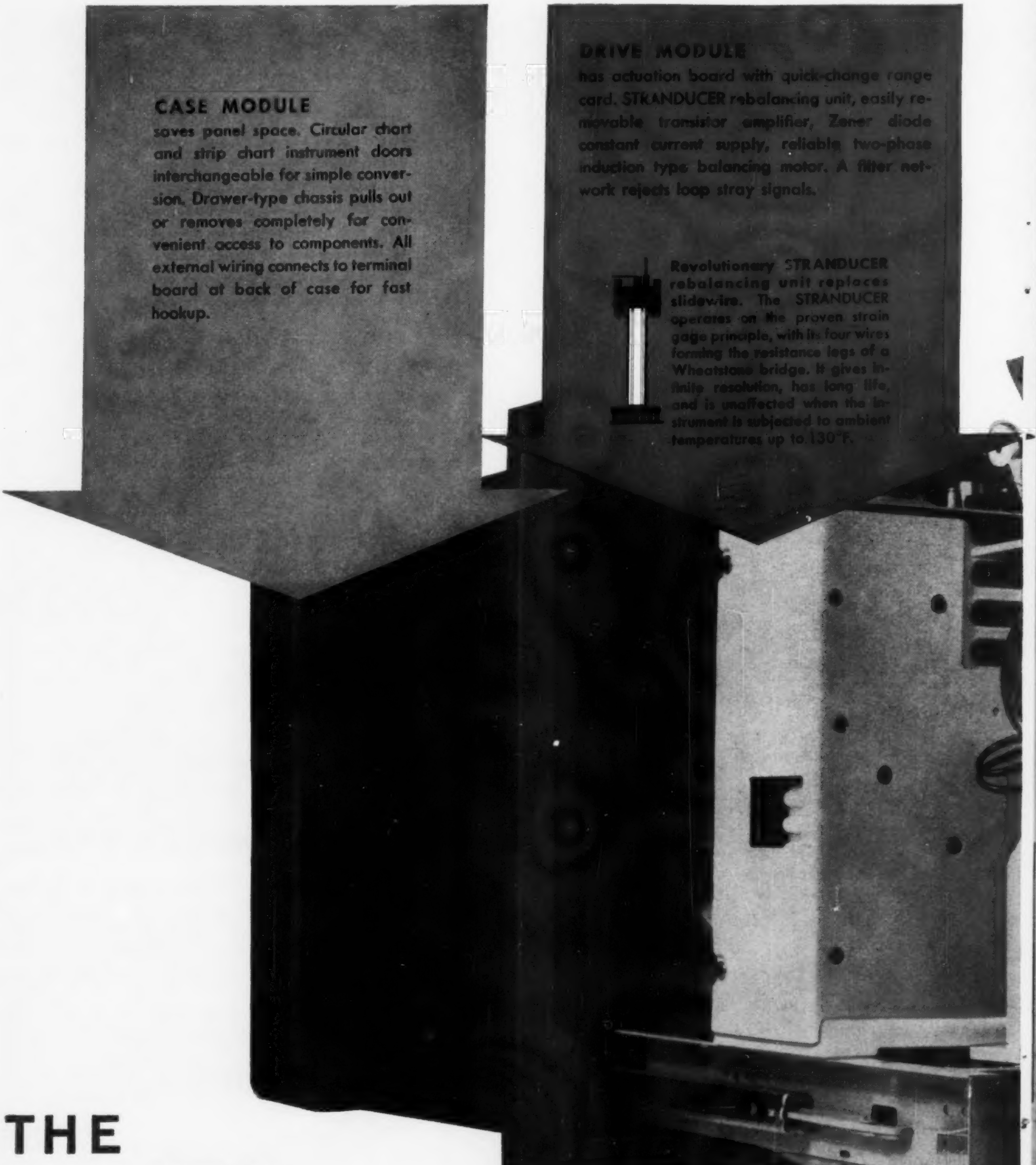
A new family of powders called concentrates incorporate features superior to "Magnaglo" and "Magnaflux" pastes such as: easier mixing, handling, and storage; a 600% increase in fluorescent brilliance; closely controlled particle size range; less foaming; and more corrosion protection. Any of eight concentrates — four for the visible Magnaflux method and four for the more sensitive fluorescent Magnaglo method — can be added directly to the oil to obtain immediately a uniform suspension. *Magnaflux Corp.*
For further information circle No. 218

Weldable Strain Gages

A line of weldable strain gages from *Baldwin-Lima-Hamilton Corp.* provides electrical stability from cryogenic temperatures through 750° F., as well as temperature compensation from 50 through 250° F. Affording high linearity over the complete temperature range, the gages are used for stress and pressure testing of nuclear reactor power loops, liquefied-gas pressure vessels, missile components, and checking of heavy machinery where down-time is at a premium.
For further information circle No. 219

Moldability Controller

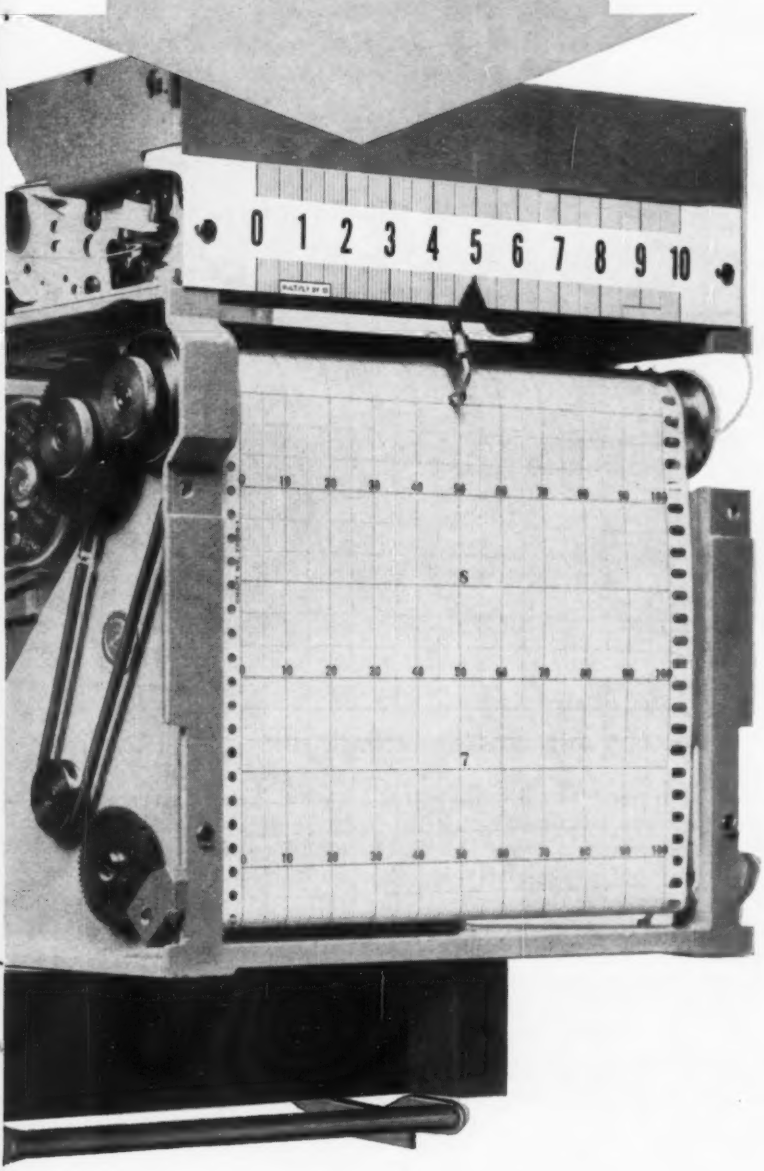
Attached to the outer shell of a sand mixer, this unit adds slurry, water and bonding agents to the sand until a predetermined moldability is obtained. As sand composition changes, the controller automatically maintains constant workability of the sand mixture. A vibrating screen divides sand samples into two streams which are continuously weighed and compared to actuate the automatic feed mechanism. *Harry W. Dietert Co.*
Circle No. 220 on request card, p. 48-B

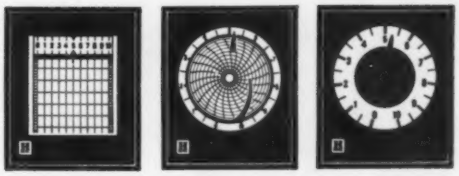


THE ALL-NEW *ElectroniK 17*

...true modular construction makes it the easiest and least expensive of all potentiometers to operate, convert and maintain

DISPLAY MODULE
is directly interchangeable with other *ElectroniK 17* front modules for conversion between strip chart, circular chart, and circular scale operation. Instruments can have up to 4 auxiliary control, and 3 zone control relays, plus the initial set point.





Here, for the first time in a small-case potentiometer, you get all the operating and maintenance advantages of modular design, plus calibrated accuracy within $\pm 0.25\%$, a revolutionary new rebalancing element, the STRANDUCER, that replaces the slide-wire, and many other time-saving, cost-cutting, performance-improving features.

Three basic modules—case, display and drive—make up the *ElectroniK 17.* The case fits standard 19-inch relay racks. Attach a carrying handle, and the instrument is portable. You can easily remove front module for simple conversion from strip chart to circular chart operation. Pull the chassis out to the service position or remove it completely without tools. Vary chart speeds ½ or 2 times basic speed (1, 2, 6, 10, or 60 inches per hour) by replacing quick-change drive gears. Change range simply by changing range cards. A Zener diode constant current supply eliminates battery problems. Plug into the instrument up to 8 contact control units for widely varied control possibilities.

ElectroniK 17 instruments are available as strip or circular chart recorders, or circular scale indicators. They can have electric contact control, with all control units of convenient plug-in design.

For the eye-opening details on great new *ElectroniK 17* instruments, call your nearby Honeywell field engineer today, or write to MINNEAPOLIS-HONEYWELL, Wayne and Windrim Avenues, Philadelphia 44, Pa. — In Canada, Honeywell Controls, Ltd., Toronto 17, Ontario.

Honeywell
First in Control
SINCE 1885

HONEYWELL INTERNATIONAL Sales and Service offices in all principal cities of the world. Manufacturing in United States, United Kingdom, Canada, Netherlands, Germany, France, Japan

Circle 506 on Page 48-B

The 16th METALLOGRAPHIC EXHIBIT

Detroit, October 23 to 27, 1961

All metallographers—
everywhere—
are cordially invited to
display their best work.

RULES FOR ENTRANTS

Exhibitors do not need to be members of the American Society for Metals.

Work which has appeared in previous metallographic exhibits held by the American Society for Metals is unacceptable.

Photographic prints should be mounted on stiff cardboard, extending no more than 3 in. beyond edge of print in any direction; maximum dimensions 14 by 18 in. (35 by 45 cm.). Heavy, solid frames are unacceptable.

Entries should carry a label on the *face of the mount* giving:

Classification of entry.

Material, etchant, magnification and other desirable data.

A brief statement (if desired) calling attention to any unusual aspect of the entry.

The name, company affiliation and postal address of the exhibitor should be placed on the *back of the mount* together with a request for return of the exhibit if so desired.

Entrants living outside the United States should send their micros by first-class letter mail endorsed "Photo for Exhibition — No Commercial Value — May Be Opened for Customs Inspection".

Exhibits must be delivered before Oct. 10, 1961, either by prepaid express, registered parcel post or first-class letter mail, addressed:

Metallographic Exhibit
American Society for Metals
Metals Park
Novelty, Ohio, U. S. A.

CLASSIFICATION OF MICROS

Class 1. Irons and steels, cast and wrought
Class 2. Stainless steels and heat resisting alloys
Class 3. Aluminum, magnesium, beryllium, titanium and their alloys
Class 4. Copper, nickel, zinc, lead and their alloys
Class 5. Uranium, plutonium, thorium, zirconium and reactor fuel and control elements
Class 6. Metals and alloys not otherwise classified
Class 7. Series showing transitions or changes during processing
Class 8. Welds and other joining methods
Class 9. Surface coatings and surface phenomena
Class 10. Slags, inclusions, refractories, cermets and aggregates
Class 11. Electron micrographs using replicas
Class 12. Electron micrographs (transmission)
Class 13. Color prints in any of the above classes
Class 14. Results by unconventional technique

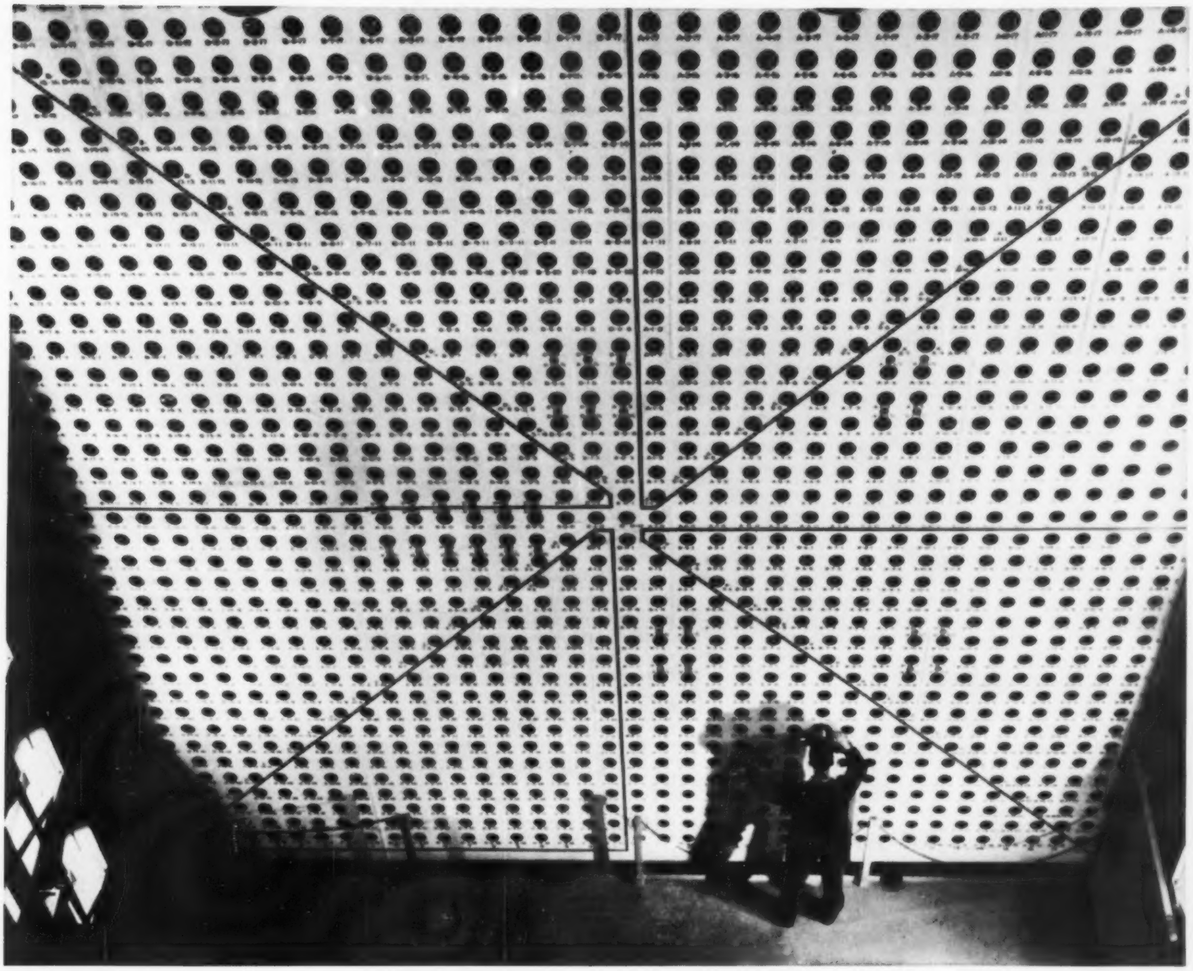
AWARDS AND OTHER INFORMATION

A committee of judges will be appointed by the Metal Congress management which will award a First Prize (a medal and blue ribbon) to the best in each classification. Honorable Mentions will also be awarded (with appropriate medals) to other photographs which in the opinion of the judges closely approach the winner in excellence. A Grand Prize, in the form of an engrossed certificate and a money award of $500 from the Adolph I. Buehler Endowment will also be awarded the exhibitor whose work is judged best in the show, and his exhibit shall become the property of the American Society for Metals for preservation and display in the Society's national headquarters.

All prize-winning photographs will be retained by the Society for one year and placed in a traveling exhibit to the various Chapters.

43rd NATIONAL METAL CONGRESS & EXPOSITION

Cobo Hall, Detroit — Oct. 23 to 27, 1961



 Circle 507 on Page 48-B

Inspector measuring pole face gap to a tolerance of ±.005".

Yoke made of five forgings held together with dowels loaded to 350,000 pounds tension by a hydraulic bolt stretcher.

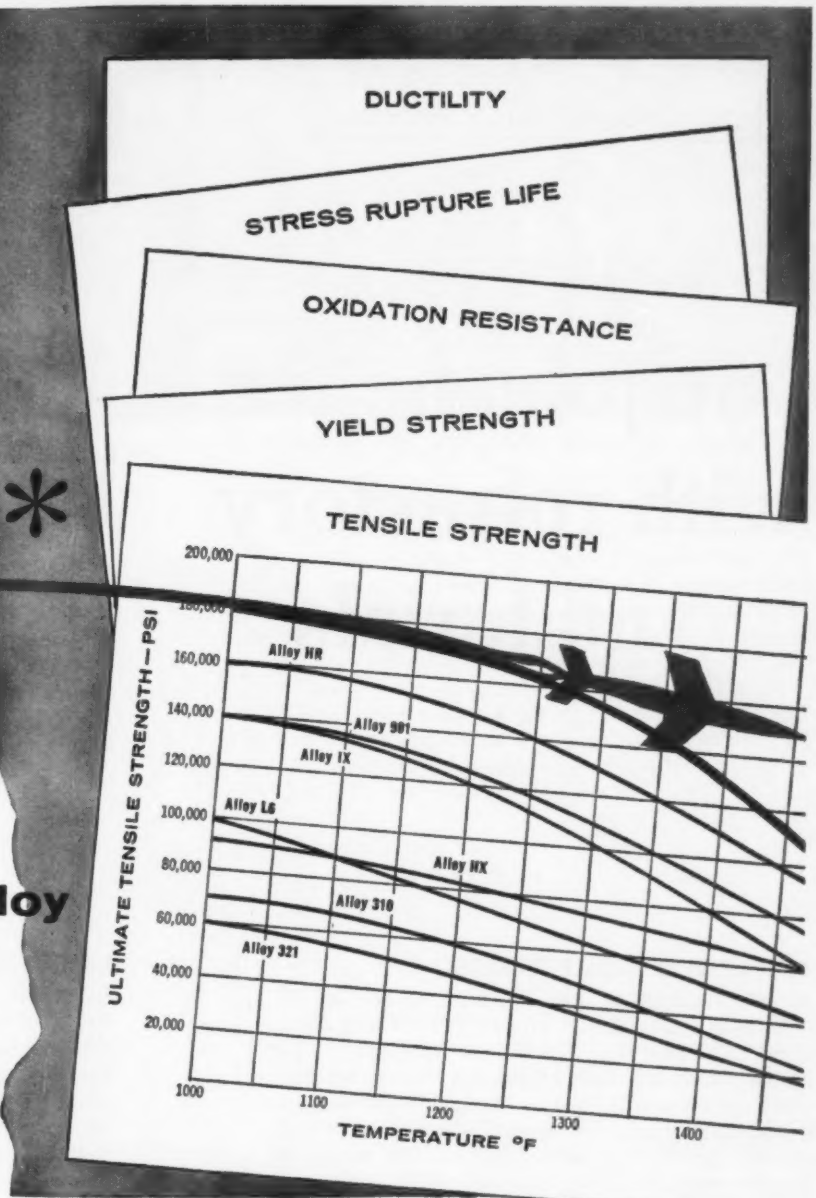
Circle 508 on Page 48-B

HIGH

on every chart:

RENÉ 41*

most dependable alloy in use today in the 1200°-1800°F range



In *all* ways, René 41 is a remarkable alloy. No other high-temperature alloy used in production today equals its tensile strength. In other properties, too, René 41 is far ahead of the field.

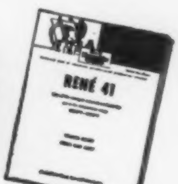
Also important, this nickel-base, vacuum-melted alloy is easy to work with. It's readily formable by drawing, bending, spinning — welds to similar or dissimilar materials.

Cannon-Muskegon offers René 41 in standard 36"x 96" sheets .015" to .125" thick, in smaller sizes down to .010", in bar stock up to 3" in diameter . . . foil down to .001 in thickness . . . and fine wire only .0015 in diameter.

For complete details, write for Technical bulletin No. 86.

*TM of General Electric Co.

ULTRAMET
VACUUM ALLOYS



CANNON-MUSKEGON CORPORATION

2879 Lincoln Avenue • Muskegon, Michigan

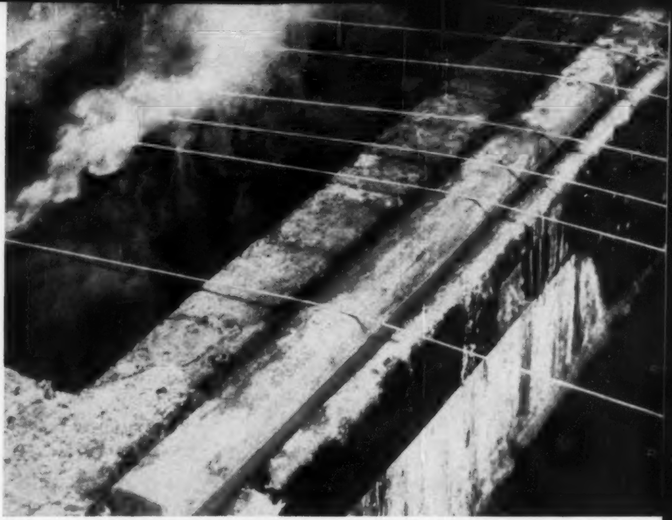
METALLURGICAL SPECIALISTS

1-59

Circle 509 on Page 48-B

Report from Carborundum:

6 ways to do jobs better with refractory materials



HANDLING MATERIALS IN ACID SOLUTIONS:

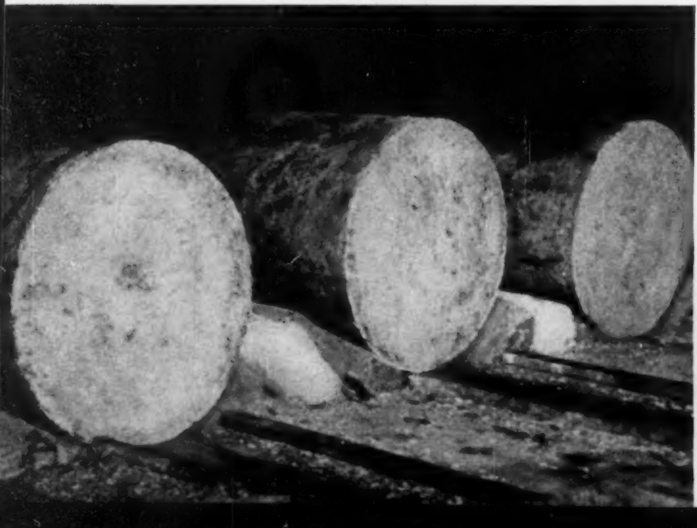
SILICON CARBIDE WEAR BLOCKS RESIST CORROSION AND ABRASION. Steel wire moving at 100 ft/min passes over CARBOFRAX® silicon carbide wear blocks to a pickling tank in the photo above. A 15% solution of sulfuric acid at 400 F is used. Sinker blocks are also of CARBOFRAX silicon carbide. Despite the action of the acid and the abrasion of the wire, the silicon carbide shows no wear after months of service. Similar applications involving Carborundum refractories are found in aluminizing and other wire coating baths.

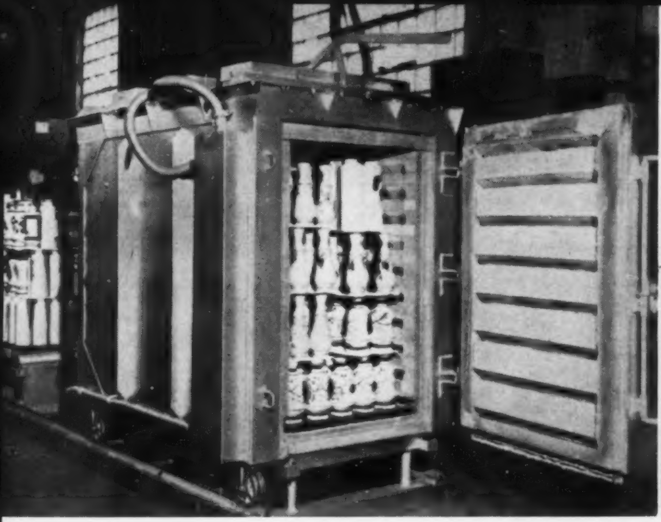
SKID RAILS IN REHEAT FURNACE:

SILICON CARBIDE RAILS LAST 30 TIMES AS LONG AS STEEL IN HIGH TEMPERATURE, ABRASIVE SERVICE. The 6¾" x 8" brass billets seen in the picture are pushed through a 38-foot long gas-fired extrusion mill furnace. Steel skid rails required replacement every five weeks. When CARBOFRAX silicon carbide rails were installed, 156 weeks of service were obtained. Reduction in downtime resulted in lower operating costs and higher production rates. Superior wear resistance and ability to withstand high temperatures make silicon carbide a profitable choice for applications like this.

LONGER LIFE FOR BURNER RINGS:

SILICON CARBIDE CONSTRUCTION WITHSTANDS FLAME EROSION AND HIGH TEMPERATURES. Refractory burner rings in pulverized coal-fired boiler frequently fail fast because of the abrasive action of the fuel particles and thermal shock due to intermittent operation. Many users have found an answer to the problem in CARBOFRAX silicon carbide rings. Silicon carbide is not only superhard, but also stays hard at high temperatures. High thermal conductivity and resistance to thermal shock minimizes cracking and spalling. Flame patterns are maintained.





DIRT-FREE OPEN FIRING WITH MOVABLE KILN:

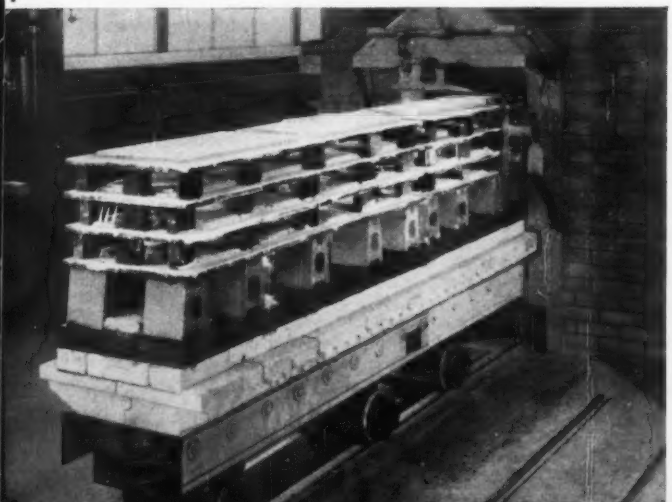
FIBERFRAX® CERAMIC FIBER LINING REPLACES BRICK: MAKES POSSIBLE TEMPERATURES UP TO 2200 F. The interesting movable kiln illustrated is made by Unique Kiln Co., Hillsdale, N. J. It moves on rails to enclose a stationary loading bed. Two beds can be serviced alternately. Door and hood linings of Carborundum's light-weight FIBERFRAX ceramic fiber, in block form, eliminate the problem of dislodged dirt and dust encountered with fireclay type refractories, which often damage ware being fired. High heat resistance and insulating properties of FIBERFRAX fiber make possible firing up to 2200 F.

SHAPES AND JIGS MACHINED FROM CERAMIC:

BORON NITRIDE IS EASILY MACHINED; RESISTS HIGH TEMPERATURES AND CORROSION. The photo shows the machining of a semi-conductor jig from Boron Nitride, a self-bonded material made by Carborundum. Close tolerances, high surface finish and intricate detail are possible. Boron Nitride offers advantages in semi-conductor production compared with graphite jigs, yields from which often drop 40% after only 50 cycles. The material also offers possibilities for insulating tubes and shapes; chemical equipment parts, crucibles, brazing fixtures, gaskets and seals. Shapes withstand furnace temperature of 3000 F; powder as high as 5400 F.

ELIMINATING CRACKING IN KILN CAR TOPS:

COMBINATION OF REFRACTORIES SOLVES PROBLEM IN CERAMIC INDUSTRY. Used in a gas-fired electrical porcelain kiln, the cars illustrated have been in service for more than two years at cycles of 14 to 15 hours, operating from cold to 2290 F to cold. Car top cracking due to heat shock has been eliminated by use of three different Carborundum refractories—a bottom layer of MULLFRAX® electric furnace mullite for high load carrying capacity, a middle course of ALFRAX® alumina "bubble" brick for insulation and an upper course of CARBOFRAX silicon carbide tile for resistance to thermal shock.



Want help on your problems?

Carborundum engineers will be glad to recommend refractories to answer your specific needs.

For information, contact Dept. M-71, Refractories Division, Carborundum Co., Perth Amboy, N. J. Descriptive brochures available on request. Please specify the area or areas of particular interest to you.

for engineered refractories...count on

CARBORUNDUM®

Circle 510 on Page 48-B

Meet our new baby giant . . . *the M-G Powered INDUCTO INTEGRAL 15*

. . . you'll never again be satisfied with Spark-Gap Melters

Inductotherm now offers the greatest space-saving, most economically-operated induction melting system in history. Once you've compared the Inducto Integral 15, you'll never be satisfied with a spark-gap converter. What's more, the 15-kilowatt Integral 15 has the same melting capacity as 20-Kw spark-gap units.

Compare Installation The entire unit occupies only 35" x 40" of floor space. The motor-generator, capacitors, transformers, and all controls are packaged in a single, compact console. Completely pre-assembled and pre-tested before delivery . . . all you do is tie-in power and water lines and you're ready to start melting. Radio shielding problems are eliminated.

Compare Operation Whatever your melting problem . . . in small foundries, in research laboratories . . . you achieve optimum power for fast, efficient melting with minimum metal loss. In addition, the Integral 15 easily maintains a balanced 3-phase load . . . you can connect two furnaces to one power control . . . and it's readily adapted for vacuum melting.

Compare Maintenance No more hydrogen to purchase, store, feed, and dispose. Moreover spark-gap converters operate at extremely high voltages with peaks up to 20,000 volts, while the Integral 15 operates at a constant 220 or 440 volt coil voltage. Safety factors increase, . . . arcing problems drop almost 99 percent. Costly mica insulation between coils is eliminated. In fact, the *only* maintenance needed is routine lubrication.

Compare Cost The Integral 15 costs a little more than spark-gap units. But you start saving money the minute you start operation . . . in time, metal, maintenance and power consumption. You can amortize the cost differential in a matter of months. And your savings are the same whether you purchase an Integral 15 outright or use Inductotherm's unique rental or lease-purchase plans.

Compare the Facts We'll gladly send you complete details on the Integral 15. Write for Bulletin 20-15. Other Inducto "Integral" models available with capacities of 30, 50, and 100 Kw. Address: Inductotherm Corporation, 412 Illinois Avenue, Delanco, New Jersey.

INDUCTOTHERM

Special Trade-In Offer

Realizing that the Integral 15 obsoletes many spark-gap units just a few years after purchase, Inductotherm plans to share this early obsolescence with their customers by offering a trade-in allowance of 50% of the original purchase price of 20 Kw Inducto spark-gap converters toward the purchase of the new Integral 15. This offer applies only to original purchasers of 20 Kw Inducto Melters and may be withdrawn at any time.

Circle 511 on Page 48-B

METAL PROGRESS

NEW LITERATURE

Steel

226. Alloy Steels
Bethlehem Steel Co. will send you a booklet "Quick Facts About Alloy Steels", a fundamental discussion of ferrous metallurgy.

227. Toolsteel Selector
The *Allegheny Ludlum* toolsteel "Steel-ector" booklet contains selector cards, descriptions of the various toolsteel grades, and explains individual "Data Stock lists" available for each grade.

228. Stainless Steels
Stainless steels can give your product designs many special advantages. Catalog "Armco Stainless Steels" describes more than 50 grades. *Armco Steel Corp.*

229. Comparison Chart
Peter A. Frasse & Co., Inc. announces the availability of a wall chart showing chemical analysis requirements for military army, navy, aeronautical, and federal alloy steel specifications. Also listed are specified forms and nearest corresponding S.A.E., A.I.S.I., and A.M.S. numbers.

230. 17-4PH Stainless
Armco Steel Corp. has published data on 17-4PH stainless steel; stronger than Type 416, with corrosion resistance in the 18-8 class.

231. Austenitic Stainless
8-p. booklet explains nature and occurrence of sigma phase, as well as its chemical composition, identification, and effect on mechanical properties and corrosion resistance. *Electric Steel Foundry Co.*

232. Sheet Floater
4-p. leaflet discusses a magnetic sheet floater used to facilitate handling of stacked steel sheets during production operations. *Dings Magnetic Separator Co.*

233. Stainless Products
G. O. Carlson Co. has prepared a booklet titled "Producing Stainless Steels . . . Exclusively."

234. Vacuum Melted Products
Pamphlet from *Carpenter Steel Co.* sets forth the details on "Vacumeltrol" and "Consumet" vacuum melted steels and other alloys.

235. Design Information
Booklet "Products For the Design Engineer" contains a stainless steel selector chart and data on high-strength steels, titanium, electrical steels, vacuum arc-melted steels, and other high performance metals. *Republic Steel Corp.*

236. High-Strength Steels
"GLX-W" steels are available at four minimum yield strength levels: 45,000, 50,000, 55,000 and 60,000 psi. in sheets, plates and bars. Information from *Great Lakes Steel Corp.*

237. Stainless Facilities
Eastern Stainless Steel Corp. has published a brochure entitled "This is Eastern Stainless" which lists facilities, services and products of the company.

Nonferrous

239. Extruded Copper Alloys
For imaginative and practical help in adapting extruded shapes to the economical production of intricate parts send for information from *Anaconda American Brass Co.*

240. Thorium-Magnesium Alloy
Vitro Chemical Co. will send literature on a thorium-magnesium alloy plus pure metals of the rare-earth family.

241. Molybdenum Sheet
A.S.T.M. reprint presents data on properties and applications of molybdenum-base sheet. *Climax Molybdenum Co.*

242. Copper Alloys
Special Alloys Kit No. 13 gives the facts on a range of alloys having high hardness and wear properties, excellent electrical conductivity, or free-machining properties. *Mueller Brass Co.*

243. Beta Titanium Alloy
32-p. manual on "Properties of Ti-13V-11Cr-3Al" includes data on metallurgy, design, and fabrication. *Titanium Metals Corp. of America.*

244. Molybdenum Information
Folder gives complete listing of all information available from *Climax Molybdenum Co.* on molybdenum-base alloys and steels, irons, and nonferrous alloys containing "moly."

245. "Handbook of the Alloyist"
Discusses advantages of several groups of alloys used in the electrical and electronics industries. Properties and typical applications are given. *H. K. Porter Co.*

246. Cobalt and Nickel-Base Alloys
4-p. data sheet lists physical and mechanical properties, corrosion resistance, thermal treatments, fabricating data, available forms, and applications of 13 alloys. *Cobalt Information Center.*

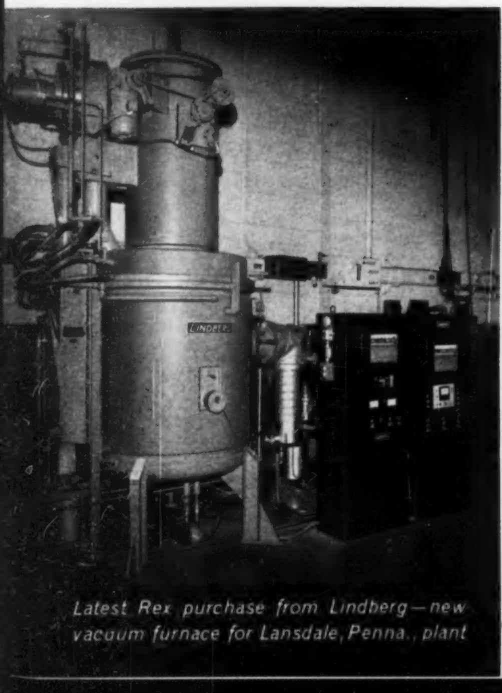
Circle appropriate number on Reply Card, p. 48-B

J. WALTER REX tells why he chose Lindberg equipment for his new Florida plant

QUOTE from Mr. Rex

"When we designed our new plant, Rex of Florida, Inc., we made sure we could provide the Florida metal working industry with complete heat treating services. After carefully surveying the industrial activities we would serve we knew we would be called upon to offer scientifically controlled, high quality heat treating for a variety of metals, both ferrous and non-ferrous, and an unusual diversity of sizes, shapes and weights. Our long experience with Lindberg furnaces and atmosphere controls assured us that we could depend on Lindberg equipment to help us meet most efficiently the widely varying demands of our Florida customers."

J. Walter Rex, President, Rex of Florida, Inc., Fort Lauderdale, with Lindberg high temperature, all-purpose furnace, one of six Lindberg units specified for this new plant. Mr. Rex, also President, J. W. Rex Company, Lansdale, Penna., is recognized as one of the foremost metal working authorities and his commercial heat treating operations are among the largest and most important in the country, particularly in treating components for rockets and missiles.



Latest Rex purchase from Lindberg—new vacuum furnace for Lansdale, Penna., plant

Mr. Rex's confidence in the ability of Lindberg equipment to meet the most exacting commercial heat treating requirements is based on the years of efficient and dependable service rendered by Lindberg units in his commercial heat treating operations. He has been a Lindberg customer for nearly 20 years. We're glad that he has found our equipment so satisfactory. We're very well satisfied with Mr. Rex as a customer, too. Altogether, including the units for Rex of Florida, Inc., he has purchased 34 Lindberg units over the years.

Lindberg offers the most complete line of fuel-fired and electric furnaces and equipment for heat treating ferrous and non-ferrous metals available to industry. If you have any problem in heat treating, get your local Lindberg representative's help now. You can depend on his experience and Lindberg's engineering and design know-how to provide exactly the right equipment for your need. And it's easy, too! Just call your Lindberg Field Engineer (he's listed in your classified phone book) or write us direct. Heat Treating Furnace Division, Lindberg Engineering Company, 2448 West Hubbard Street, Chicago 12, Illinois.

Los Angeles plant: 11937 S. Regentview Avenue, Downey, California. In Canada: Birlefco-Lindberg Ltd., 15 Pelham Ave., Toronto 9, Ont. Also, Lindberg plants in Argentina, Australia, England, France, Italy, Japan, Spain, Switzerland and West Germany.

Circle 512 on Page 48-B

LINDBERG heat for industry

247. Zirconium Metal
14-p. booklet "The Corrosion Resistance of Zirconium" contains corrosion data for over 100 highly corrosive media in concentrations up to 100% and temperatures up to 400°F. *Zirconium Association.*

248. Yttrium Metal
Yttrium metal is available in several forms. "Rare Earth and Yttrium Metals" booklet has the details. *American Potash & Chemical Corp.*

249. Titanium For Missiles
14-p. study summarizes six major application areas for titanium in missile construction. *Titanium Metals Corp. of America.*

250. Moly and Tungsten Products
General Electric Co. will send information on pressed and sintered moly and tungsten powder metallurgy billets, slabs, tubes, or preforms made from these refractory metals.

251. Beryllium Alloys
Important parts such as heavy-duty springs in submarines give more performance because of properties found in beryllium alloys. Information from *The Beryllium Corp.*

252. Bronze Alloys
Get the full story on "Ampco" metal and "Ampcoloy," a series of bronze alloys for corrosion, erosion and metal-wear applications. *Ampco Metal, Inc.*

253. Precision Castings
Chase Electronics Motor Div. has prepared literature on precision molding of high-purity (99.9%) aluminum parts.

254. Aluminum Casting Alloy
Bulletin No. 103R5 discusses "Tenzaloy" a widely used high-strength aluminum casting alloy. *Federated Metals Div.*

255. Leaded Nickel Copper
Flyer from *Anaconda American Brass Co.* announces the availability of a precipitation hardening alloy, "Leaded Nickel Copper No. 831," for electrical contacts and connectors.

Materials

257. High-Temperature Alloys
Seventeen "Haynes" alloys are compared against each other in the areas of physical, mechanical and chemical properties and stress-rupture data. 20-p. booklet from *Haynes Stellite Co.*

258. Iron Powder
Products made with iron powders provide design flexibility, reduce production costs and can be manufactured to closer tolerances. Information from *Alan Wood Steel Co.*

259. Glassed-Metal Products
16-p. Bulletin 987 describes glassed-metal pipe, valves and fittings for installations that require resistance to corrosion or processes that cannot tolerate contamination of product. *Pfaudler Co.*

260. Service at 2300° F.
Electro-Alloys Div. has issued pamphlet containing data on "Supertherm", a 26% chromium, 35% nickel alloy for service in 1800 to 2300°F. range.

261. Corrosion-Resistant Alloys
Haynes Stellite Co. is offering a 104-p. book which discusses "Haynes" corrosion-resistant alloys, their properties, forms, and the corrosives they will resist.

225. Silver Brazing Alloys

24-p. "Silver Brazing Alloy Manual" released by *Air Reduction Sales Co.* covers brazing procedures, problems and solutions. A complete range of brazing al-

loys is discussed, stressing advantages and applications. The diagrams and charts presented are useful in selecting the right alloy to meet specific engineering requirements.

262. René 41
Technical Bulletin No. 86 discusses René 41, the most dependable alloy in use today in the 1200 to 1800° F. range. *Cannon-Muskegon Corp.*

263. Super Refractories
The Refractories Div. has published "Super Refractories by *Carborundum*" which contains application and property data on special refractories.

264. Corrosion Data Charts
The corrosive effects of 400 different materials on 16 different alloy systems—including Hastelloys, Monel, Nickel, Inconel, aluminum, tantalum, titanium and zirconium—are shown in data chart published by *Nooter Corp.*

265. Refractory Metal Chart
Offered by *Fansteel Metallurgical Corp.* Lists the properties of the refractory elements tungsten, tantalum, molybdenum, and columbium.

266. High-Temperature Graphite
Speer Carbon Co. has prepared a bulletin entitled "Carbon and Graphite for High-Temperature Applications."

267. Combustion Tubes
Mullite or "Zirco" ceramic combustion tubes for service up to 3000° F. are gas tight for accurate analysis. Catalog from *McDanel Refractory Porcelain Co.*

268. High-Temperature Castings
The Duraloy Co. will send you a pamphlet covering applications for high-temperature castings used at temperatures up to 2200° F.

269. High-Alloy Castings
Brochure from *The Fahralloy Co.* tells about stainless and high-temperature alloy castings (up to 3000 lb.).

270. 4100° F. Service
Bulletin PC from *Chromalloy Corp.* describes a chromallized Mo component which withstands temperatures to 4100° F.

271. Molybdenum Dies
Sylvania Electric Products, Inc. will send information on molybdenum alloys for forging into extrusion dies for processing steel, titanium and other high-temperature alloys.

272. Pre-Alloyed Powders
4-p. Folder No. 128 tells about pre-alloyed stainless steel and high-alloy powders for "pow-met" applications, for melting stock and for applications in the electronic and chemical industries. *Hoeganaes Sponge Iron Corp.*

273. High-Temperature Coating
"Rokide" coatings resist heat, abrasion and corrosion at temperatures up to 4500° F.; are chemically inert and are good thermal insulators. Folder No. 361, *Coors Porcelain Co.*

274. Hard Metals
Bulletin CMP-1060 sets forth the details on a granular tungsten carbide, "Clecite", a high-strength, abrasion-resistant material for application in the petroleum, construction and mining industries. *Cle-Met Products Div.*

275. Graphite Heat Exchangers
8-p. catalog describes "Karbate" impervious graphite counterflow block heat exchanger. Type CFB. *National Carbon Co.*

276. Heat Resistant Castings
72-p. booklet "Heat Resistant Castings, Corrosion Resistant Castings . . . Their Engineering Properties and Applications" available from *International Nickel Co.*

277. Thermal Fatigue
Electro-Alloys Div. has published a report "The Mechanism of Thermal Fatigue" by H. S. Avery.

Tooling

278. Hot Work Toolsteel
Data Sheet 16 summarizes properties on *"Heppenstall T73"* a low-carbon, medium-tungsten hot work steel with high red hardness, intended for forging and extrusion dies in brass mills.

279. Steel-Bonded Carbides
12-p. manual describes "Ferro-Tic C" a machinable and hardenable steel-bonded carbide tool material. *Sintercast Div., Chromalloy Corp.*

280. Die Blocks
Bulletin 300 details the advantages—increased ductility and toughness—of vacuum degassing the steel which goes into die blocks and hot work toolsteels. *A. Finkl & Sons Co.*

281. Drill Presses
The Electro-Mechano Co. has released a 4-p. pamphlet which reviews line of high-speed precision drill presses.

282. Solid Lubricants
Product data sheets from *Acheson Colloids Co.* on "Emralon 320" dry-film coatings. This material does not cake, evaporate or freeze.

283. Band Sawing
Armstrong-Blum Mfg. Co. has issued a pamphlet on the "Marvel No. 81" single-cut bandsaws designed and built to reduce processing costs.

To request any item listed, circle appropriate number on Reply Card, p. 48-B

284. Tool Steels
Uddeholm Co. of America will send technical literature and stock list on all grades, sizes, and types of tool steels they manufacture.

285. Graphite Dispersions
Booklet by *Grafo Colloids Corp.* gives proper graphite dispersion for a specific operation or applications.

286. Air-Hardening Tool Steel
Bethlehem Steel Co. will send you a booklet discussing tool and die steels; includes information on "Air-4" steel which hardens in air from 1550° F.

287. Cut-Off Wheels
6-p. pamphlet illustrates line of cut-off wheels offered by *Simonds-Worden-White Co.*

288. Rust Preventative
Literature from *Baker-Gubbins Co.* on a rust inhibiting coolant used for machining and grinding of ferrous metals; free from salt-depositing characteristics.

289. Drawing Lubricant
Bulletin 45 details the advantages of "Fleximet M2DS" a metallic complex lubricant containing an additive to promote bond where no precoat is used. *Swift & Co.*

Heating

291. Heat Treating Chart
Tempil Corp's four-color chart, "Basic Guide to Ferrous Metallurgy," illustrates forging, burning, annealing, transformation, stress-relieving, nitriding, blue brittle, normalizing, and carburizing ranges, as well as grain size changes vs. temperature.

292. Radiation Thermometer
Pamphlet R-103 describes the "Model TD-6 Thermodot" which measures and controls temperature without contact. *Radiation Electronics Co.*

293. Toolsteel Identification
The *Gorham Tool Co.* has published their ninth edition of a 26-p. booklet covering classifications and symbols for identification of high-speed steels.

294. Toolsteel Guide
Written by Dr. B. L. Averbach of M.I.T., "Toolsteels", a basic guide to the use of tool and die steels has been published by *Climax Molybdenum Co.*

295. Combustion Controllers
Combustion controls for furnaces, ovens, and boilers are described in 8-p. Pamphlet 3-001 released by *The North American Mfg. Co.*

296. Chain Belt Furnaces
Bulletin No. 601 gives details on a chain belt furnace for scale-free hardening, carbon restoration, carburizing, carbonitriding or nondecarb heat treating of small and medium sized parts. *The Electric Furnace Co.*

297. Salt Baths
Catalog from *E. F. Houghton & Co.* sets forth the advantages of liquid salt baths, which provide freedom from decarburization in heat treated parts.

298. Induction Heating
"Typical Results of Tocco Induction Brazing and Soldering" will be sent to you by *The Ohio Crankshaft Co.*

299. Salt Bath Furnaces
Lindberg Engineering Co. has a pamphlet which gives the facts on "Lindberg-Upton" salt bath furnaces for uniform heat treatment at lower cost.

300. Heat Treating Equipment
Bulletin 6010B from *C. I. Hayes, Inc.* on complete line of heat treating equipment; services and facilities also described.

301. Refrigeration Cabinets
Revco Inc. offers folder "Selecting a Low-Temperature Cabinet." A variety of sizes with low-temperatures capabilities to —140° F.

302. Quenching Data
Texaco Co. has prepared a booklet "Quenching and Hardening" which contains information on steel heat treating.

303. Carburizing Furnace
Installation of a continuous carburizing furnace (replacing pack processing) will lower production costs. Information from *Surface Combustion Div.*

304. Heat Treat Ovens
Bulletin 157 from *Young Brothers Co.* discusses batch and conveyor type ovens for temperatures up to 1000° F.

305. Shaker Hearth Furnace
Catalog MP-607 describes shaker hearth furnaces for bright annealing and hardening up to 100 lb. of stainless steel parts per hr. at temperatures up to 2000° F. *American Gas Furnace Co.*

306. Induction Heating Units
The *Lepel High Frequency Laboratories, Inc.* will send catalog discussing line of high-frequency induction heating units for hardening, annealing, zone refining and brazing.

307. Heat Treating Salts
Eliminate scaling and decarburization in heat treating without special atmospheres—through use of "Aeroheat" salt baths. Data from *American Cyanamid Co.*

308. Gas Burners
"Buzzer" burners need no blowers, power or other auxiliary equipment to effect combustion; simply connect to available gas supply. Catalog from *Charles A. Hones, Inc.*

309. Program Control
Can your process benefit from programmed heating and cooling? "L & N" cam-type program controls reproduce your time and temperature cycles exactly. Data from *Leeds & Northrup.*

310. Heat Processing
Selas Corp. of America will send information on automatic straight-line heat processing equipment for soldering and brazing applications.

311. Refrigeration Systems
Data sheet and catalog give full information on *Harris Mfg. Co.* "Cascade" refrigeration systems for low-temperature industrial uses.

312. Temperature Controls
Bristol Co. has issued a leaflet presenting data on pyrometers and accessory equipment.

313. Heat Exchanger
Bulletins 120, 124, and 132 explain the "Aero" heat exchanger for controlling the temperature of quench baths. *Niagara Blower Co.*

314. Sintering Furnaces
For detailed information on mesh-belt sintering furnaces send for Bulletin MSF-361 from *Harper Electric Furnace Corp.*

315. Temperature Crayons
The *Markal Co.* has published a pamphlet on "Thermomelt" temperature indicating crayons: accurate to within 1%; range 113 to 2000° F.

316. Heat Treating Furnace
Bulletin 219 from *Johnston Mfg. Co.* describes a bottom-charged, controlled-

Circle appropriate number on Reply Card, p. 48-B

Carbon/Graphite Facts for METALLURGISTS

NATIONAL
TRADE MARK

INJECTION and FLUXING TUBES
for ferrous and non-ferrous metal treatment

FOR use in degassing non-ferrous metals, or for the injection of graphite powders beneath the surface of molten iron, NATIONAL graphite tubes provide the most satisfactory material. They resist thermal shock, are non-contaminating, and have no affinity for metal or dross. Tubes are stocked in a wide range of sizes for immediate shipment.

Circle No. 459 on Page 48-B

GRAPHITE POWDERS
give fast, high-rate recovery and primary control at low cost

NATIONAL graphite powders—ranging in size from very fine flour to coarse particles—are available for a wide variety of applications. Fineness and maximum ash content are held within closely controlled limits. A few uses include: injection or inoculation of ferrous metals, mold washes, powder glazing, lubricants, and powder metallurgy applications. For complete list and specifitions, request Catalog Section S-7655.

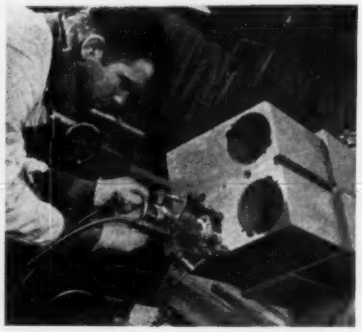
Circle No. 460 on Page 48-B

HEAT TREATING ACCESSORIES
Boats, Trays, Jigs, Discs, and Plates

HEAT treating accessories of NATIONAL graphite provide a combination of advantages not found in other materials. They are longer lasting, non-contaminating, and will not warp, crack or soften in use. Special shapes are easily machined to close tolerances. Among the many uses for these graphite accessories are: powdered metal and carbide sintering, zone refining, furnace brazing, fusion of elements into semi-conductor wafers, and other furnace processing.

Circle No. 461 on Page 48-B

MACHINING
of graphite is a skilled operation at NATIONAL CARBON



MACHINING to close tolerances is a regular practice of NATIONAL CARBON. Graphite can be turned, sawed, bored, milled, drilled, planed, shaped, ground, tapped, reamed, honed, or lapped. Whatever your requirements—simple or intricate shapes—NATIONAL CARBON's strategically located plants have the equipment and skilled craftsmen to meet your most rigid specifications. Contact us . . . graphite may also solve your problems.

Circle No. 462 on Page 48-B

"National," "Union Carbide," "N" and Shield Device are registered trade-marks for products of

NATIONAL CARBON COMPANY
Division of Union Carbide Corporation • 270 Park Avenue, New York 17, N. Y.
IN CANADA: Union Carbide Canada Limited, Toronto

UNION CARBIDE

atmosphere, batch-type heat treating furnace with automatic quench.

317. Furnace Controls
Minneapolis-Honeywell has released a pamphlet describing the "Electr-O-Line" control unit for position-proportioning control with reset and rate action.

318. Radiant Tubes
Alloy Engineering Co. has information on heating and cooling tubes and tube assemblies made from any heat and corrosion resistant metal.

319. Metal-Mesh Belts
130-p. reference manual from *Cambridge Wire Cloth Co.* on metal-mesh belts in nine basic weaves, made from standard and special alloys.

320. Portable Potentiometer
Thermo Electric Co. has issued 4-p. Leaflet 64-1 on a "Minimite" portable potentiometer indicator.

321. Temperature Transmitter
8-p. Specification Sheet S630-1 outlines features and ordering information on a pneumatic temperature transmitter which uses a filled thermal system. *Minneapolis-Honeywell.*

322. Miniature Thermocouples
Bulletin No. 4336 describes line of micro-miniature thermocouples, world's smallest and fastest temperature sensors. *Baldwin-Lima-Hamilton Corp.*

323. Tank Heaters
8-p. Brochure No. 1623 illustrates vertical and horizontal tank heaters and gives complete rating data for all sizes of tanks and duties. *Griscom-Russell Co.*

324. Open-Coil Gas Alloying
For a stronger tin plate use the open-coil gas process to control carbon and nitrogen level. *Lee Wilson Engineering Co.*

325. Thermocouple Cables
Catalog G100-2 explains multiple-conductor T/C extension cables; available with from 4 to 48 pairs of solid-conductor temperature-compensated wires. *Minneapolis-Honeywell.*

326. Heat Treat Baskets
24-p. pamphlet from *Stanwood Corp.* tells the story about heat treating equipment, such as stocking fixtures which reduce weight.

327. Temperature Indicators
Tempil Corp. has released a leaflet which gives the complete story on temperature crayons. Free sample of temperature pellet also available.

328. Heating by Induction
56-p. catalog sets forth details on induction heating equipment for hardening, brazing, soldering, forging, annealing, melting, sintering and welding applications. *Induction Heating Corp.*

Finishing

330. Surface Treatments
Conversion Chemical Corp. will send you a fact sheet containing details on 40 products including chromate coatings and bright dips for ferrous and nonferrous alloys.

331. Electroplating Processes
24-p. Bulletin EP-102 discusses 18 electroplating processes, including three new nickel plating operations. *Hansen-Van Winkel-Munning Co.*

332. Nickel Alloy Plating
No other process can apply a hard, corrosion resistant nickel-alloy coating without the use of electricity. Get the facts on the "Kanigen" process from *General American Transportation Corp.*

333. Plating Chemicals
80-p. bulletin "Chromium Chemicals" presents data on mutual chromic acid and other chromium chemicals. *Solvay Process Div.*

334. Phosphate Coatings
Brochure from *Turco Products, Inc.* discusses "Paintite", an iron phosphate coating that provides a better bond for organic finishing.

335. Chemical Milling
16-p. brochure from *Eastman Kodak Co.* describes "Metal-Etch Resist" a chemical milling process which speeds up weight-reduction jobs and parts manufacture.

336. Selective Plating
6-p. leaflet describes line of "package" selective plating plants and equipment. *Selectrons, Ltd.*

337. Industrial Coatings
4-p. flyer tells about 18 special industrial coatings for: product protection, improvement of appearance, mold or die release, or dry lubrication. *S. C. Johnson & Son, Inc.*

338. Centrifugal Galvanizers
Folder from *Barrett Co.* describes centrifugal galvanizers. Rapid acceleration snaps off excess metal and speeds up production.

339. Plating Filters
The *Udylite Corp.* has released a specification sheet on side-opening electroplating filters.

340. Metal Cleaner
Data sheet tells how to use "Houghto Clean 220" an efficient metal cleaner; it leaves a film which protects against rust. *E. F. Houghton & Co.*

341. Drying Ovens
Carl Mayer Corp. has issued Bulletin DO-61 outlining many advantages of industrial drying ovens.

342. Printed Circuit Plating
The *Meaker Co.* has prepared a product bulletin which gives details and application data on "Deoxyde" a formulation which removes oxides, light soils, and finger marks by means of a simple dipping operation.

343. Abrasive Wheels
Data Sheet No. FD-30 illustrates applications of "Type B Flex Drum" an abrasive cloth wheel that simplifies polishing and sanding of complex contoured surfaces. *Merit Products.*

344. Iron Phosphate Coating
Oakite Products, Inc. has issued Bulletin F-9475 on "Cryscoat" iron phosphate coatings which reduce cost of corrosion protection for steel products.

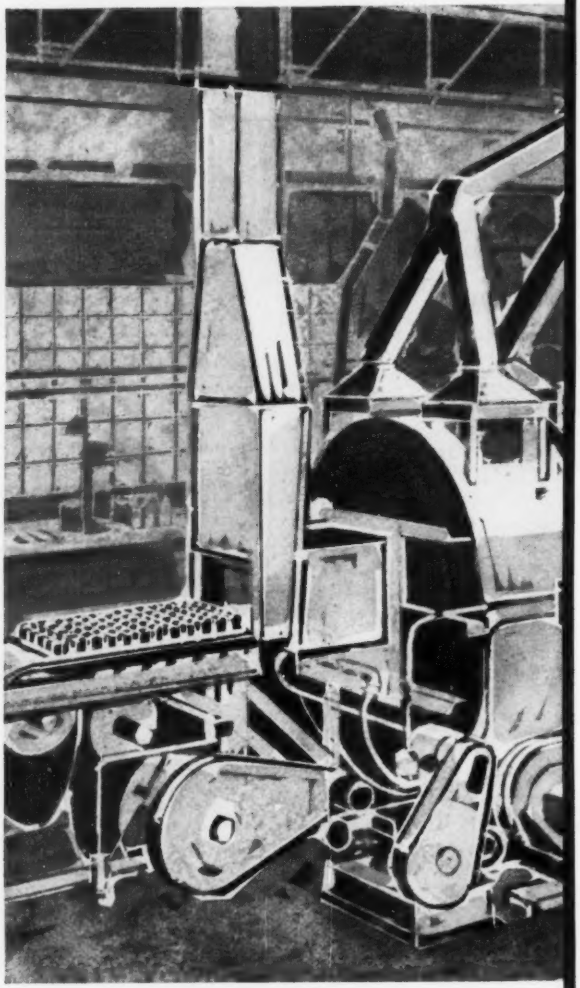
345. Plastic Coating
A 4-p. pamphlet on "Pfaudlon 301," a corrosion-resistant plastic coating for metal, is available from *The Pfaudler Co.*

346. Blast Cleaning
Pangborn Corp. has released a leaflet setting forth the details on "Rotoblast" steel shot and grit.

Welding

348. Welding and Brazing
56-p. catalog and instruction manual covers welding, brazing, soldering and fluxes. Properties, uses and application data included. *All-State Welding Alloys.*

Circle appropriate number on Reply Card, p. 48-B



The most precise temperature control of its kind at the best price!

$150

R7086 POTENTIOMETER CONTROLLER

This transistorized Potentiometer Controller is available for ranges up to +3000°F. The sensitivity of the controller is 120 microvolts irrespective of span. Time proportioning standard at no extra cost. Available with on-off or 2-positioning. Other features include illuminated dial, flashing lights to indicate when temperature is at "set" point, and an 8" scale for easy setting. Thermocouple burn-out protection inherent in design. Controllers can be surface or flush mounted. Other models with centigrade scales are also available.

Honeywell

First in Control

SINCE 1885

HONEYWELL INTERNATIONAL

Sales and service offices in all principal cities of the world. Manufacturing in the United States, United Kingdom, Canada, Netherlands, Germany, France, Japan.

Circle 515 on Page 48-B

349. "Guide to Better Welds"
80-p. booklet discusses causes and cures of common welding troubles, essentials for proper welding, and electrode selection. *Hobart Brothers Co.*

350. Welding Stainless
Information concerning techniques for welding stainless steel is contained in *Lincoln Electric Co.* Bulletin 7300.2 entitled "Arc Welding Stainless Steel".

351. Nickel Alloys
Wall Colmonoy Corp. has issued Data Sheet T-1 which discusses relative corrosion resistance of "Colmomoy" nickel alloys.

352. Silver Brazing
Bulletin 20 gives a good picture of silver brazing and its benefits; includes details on alloys, heating methods, joint design and production techniques. *Handy & Harmon.*

353. MIG Welding
The *Miller Electric Mfg. Co.* has released a booklet on 200, 300 and 500-amp. variable-slope MIG welding machines.

354. Electron Beam Welder
The "E-Beam Mark VI" electron welder makes possible welding and brazing of many refractory and reactive metals. Data from *Alloyd Electronics Corp.*

355. Semiconductor Fabrication
Semi-Alloys Inc. offers data sheets on aluminum, gold, indium and silver alloys for semiconductor fabrication.

356. Welding Periodical
Vol. 5, No. 9 of a 16-p. welding periodical issued by *Sciaky Bros., Inc.* reports on practical methods of profitable assembly with fusion, electron beam and resistance welding techniques.

357. Welding and Cutting
Linde Co. will send literature on two TIG welding and cutting outfits, for double performance and dual savings.

358. Hardfacing Electrodes
44-p. brochure issued by *Air Reduction Sales Co.* covers hardfacing electrodes and wires.

359. Silicon Rectifiers
6-p. folder, GEA—7066, provides information on features, operating characteristics and construction of a line of d-c. power supplies, rated 0.75 to 75 Kw. *General Electric Co.*

360. Bronze Welding Wire
Ampco Metal, Inc. will send data on "Ampco-Trode 7" (ECuAlA-1) an iron-free aluminum bronze arc-welding wire and filler rod for overlay applications, where high hardness is not required.

361. Brazing Alloys
American Platinum & Silver Div., Engelhard Industries has prepared literature on low-temperature silver brazing alloys and fluxes.

362. Welding Electrode
Pamphlet from *Metal & Thermit Corp.* sets forth the details on an improved all-position E-7108 low-hydrogen iron-powder electrode for a-c. or d-c. reverse polarity welding.

Testing

364. Specimen Mounting Material
The Fulton Metallurgical Products Corp. has published a brochure describing "Quickmount", a fast-setting, self-curing specimen mounting material that produces clear mounts without application of heat or pressure.

365. Spectrographer's News Letter
The Vol. 14 No. 1 issue of a quarterly published by *Applied Research Laboratories* contains the article "Foundry Control of Cast Iron With a Direct-Reading Vacuum Spectrometer."

366. Fatigue Testing Machine
Brochure RF-2-61 explains the "Riehle-Los" hydraulically actuated fatigue testing machine includes specifications, hydraulic flow charts, and data on accessories. *Riehle Testing Machines Div.*

367. Instrument Charts
Bulletin Y1906 from *The Bristol Co.* gives complete story on all types of charts up to 32 in. wide (strip charts) and up to 12 in. diameter (round charts) recording in ink, hot stylus, light beam, or by electro-sensitive techniques.

368. Universal Tester
Booklet describes the "Wiedemann-Baldwin Model HV" universal testing machine which offers low-cost testing without sacrificing quality and accuracy. *Wiedemann Machine Co.*

369. Metallurgical Microscopes
Get more microscope for the money. Pamphlet 2-P details the advantages of *Unitron Instrument Co.* microscopes and accessory equipment.

370. Spectrographic Electrodes
"SPK" grade preformed electrodes combine high purity and improved uniformity for better reproducibility of analyses. Details from *National Carbon Co.*

371. Laboratory Microscopes
Bausch & Lomb "Dynazoom" laboratory microscopes with continuously variable optical systems illuminate hidden details that spell out the whole story in a specimen, regardless of the specific magnification.

372. Ductility Testers
Steel City Testing Machines, Inc. has released a pamphlet which tells about a ductility tester for controlling drawing quality of sheet metal.

373. X-Ray Unit
Leaflet from *Westinghouse* discusses the "Baltospot 150" industrial x-ray unit which will penetrate 1⅝ in. of steel.

374. Electron Microscope
Radio Corp. of America will send information on electron microscopes, adaptable to a wide range of applications.

375. Brinell Machines
Faster hardness testing is possible with a long-stroke Brinell testing machine. Data from *Detroit Testing Machine Co.*

376. Hardness Testing
Clark Instrument, Inc. has prepared a booklet which tells all about hardness testing. Hardness conversion chart also available.

377. Photomicrographic Cameras
Brochure SB682 from *American Optical Co.* describes line of "Spencer" photomicrographic cameras.

378. Superficial Tester
Wilson Mechanical Instruments Div. will send you Catalog RT-58 which discusses the superficial hardness tester as well as a full line of "Rockwell" hardness testers.

379. Chart Recorder
Bulletin TT12-3 from *Tinius Olsen* reviews the facts on a moveable XY strip chart recorder—for increased testing flexibility.

380. Listing of Test Machines
Testing Machines, Inc. has prepared a 20-p. list of testing machines for all industries. A total of 461 testing machines is covered in 69 testing categories.

Circle appropriate number on Reply Card, p. 48-B

381. Stress Analysis
Bulletin No. 3 from *Doehler-Jarvis Div.* contains an article "Stress Analysis as a Guide to Structural Design".

382. Testing Machines
4-p. Bulletin G-361 illustrates line of testing machines for Brinell hardness, ductility, tensile, compressive, transverse and strength; also hydrostatic and pneumatic machines, proving rings, calibration presses and special testing machines. *Steel City Testing Machines.*

383. Research Activities
30-p. Booklet covers *General Mills* extensive research activities in the physical sciences—electron and surface physics, ion and plasma physics, chemistry and materials, and electrohydrodynamics.

394. Universal Testing Machine
Instron has prepared a brochure discussing advanced materials testing techniques and equipment including a complete line of universal testing machines.

395. Metallographs
Find out how you can make faster, easier, completely dependable analyses and save time and materials. Send for catalog E-232 from *Bausch & Lomb.*

Casting

397. Nickel Briquets
Brochure from *Foote Mineral Co.* contains price and delivery information on high-purity "Sherritt" nickel briquets with low hydrogen content.

398. Meehanite Castings
4-p. Folder B-48 details the advantages of "AQ Meehanit" air-hardenable, nondistorting iron castings. *Meehanite Metal.*

399. Flux Treatment
Molybdenum Corp. of America will send information on "MCA Flux" used in treating large rimming ingots and in maintaining the deep drawing quality of smaller ingots.

400. Foundry Resin
Flyer from *Union Carbide Plastics Co.* gives details on a bakelite phenolic resin "BRS-5575" which produces a fast curing cold-coated sand suitable for shell molds and cores.

401. Heat Treatment of Stainless
24-p. research report "Heat Treatment and Properties of Cast, Hardenable Stainless Steels" is offered by *WaiMet Alloys.*

402. Ramming Mix
Kaiser Refractories & Chemicals Div. has released a folder containing data on "Permanente 84", a basic patching and ramming mix for use in openhearth furnaces.

403. Vanadium Additions
Vanadium in tool steels produces stronger, tougher tools that hold a cutting edge. Data on ferrovanadium, vanadium oxide, and self-reducing vanadium from *Union Carbide Metals Co.*

404. Castable Refractories
Pamphlet R-35A gives information on refractory castables for high-temperature processing. *Babcock & Wilcox Co.*

405. Exothermic Alloys
Vanadium Corp of America will send details on line of exothermic alloys including ferrochromium, ferrosilicon, ferrochrome-silicon and ferrovanadium.

412. Furnace Refractories
24-p. brochure outlines physical characteristics of a variety of castable refractories and presents application data in furnaces operating at temperatures from 700 to 3500° F. *Kaiser Refractories & Chemicals Div.*

413. Steel Castings
4-p. data sheet entitled "How to Determine Riser Sleeve Sizes For Steel Castings" has been published by *Foseco, Inc.*

414. High-Vacuum Valves
26-p. Bulletin 10-1 from *Consolidated Vacuum Corp.* gives details on high-vacuum valves, baffles and traps.

415. Special Castings
Pamphlet describes techniques and facilities of Specialty Foundry Div. of *Lebanon Steel Foundry.* High integrity castings with precise dimensional and surface control; simple and complex designs in a wide range of alloys.

416. Casting Design
Booklet "How to Design Precision Investment Castings" is available from *Midwest Precision Castings Co.*

417. Core Binder
A heavy-duty cereal binder flour makes possible reduction in usage levels of up to 20%, while providing physical properties equal to other binder flours. Information from *General Foods Corn Mill Div.*

418. Insulating Firebrick
35-p. bulletin presents a complete discussion of the advantages of insulating firebrick, as well as chart data on a variety of applications. *Babcock & Wilcox Co.*

419. Refractory Castables
Universal Atlas Cement Div. will send details on "Lumnite" cement, a calcium-alumniate refractory castable for monolithic linings.

Parts

421. Roll-Formed Shapes
If you require ferrous, nonferrous, clad or embossed shapes with a uniform, quality appearance ready for your production lines send for Catalog 760 from *Roll Formed Products Co.*

422. Expanded Metal
36-p. Catalog No. 61 illustrates 38 decorative expanded-metal designs and gives specifications. *Southern Electric, Inc.*

423. Thread-Cutting Screws
Available from *Parker-Kalon Div.*, a 6-p. leaflet illustrates thread-cutting screws and gives data on design, sizes, material applications, recommended hole sizes, and minimum penetration in blind holes.

424. Tubing Buyers Guide
Characteristics, size ranges and relative costs of carbon and alloy steel tubing for mechanical, structural and hydraulic applications are set forth in Bulletin 12-10 from *Joseph T. Ryerson.*

425. Screen System Design
Booklet illustrates "Curtainscreen" system of components for forming interior and exterior screens. *Julius Blum & Co.*

426. Threaded Inserts
Newton Insert Co. offers a 28-p. catalog containing data on 20 different series of "Keensert" threaded inserts and studs.

427. Bolted Assemblies
4-p. folder shows how to take the guess work out of bolted assemblies and assure maximum clamping force from threaded fasteners. *Skidmore-Wilhelm Mfg. Co.*

Circle appropriate number on Reply Card, p. 48-B

Why Ammonia?

Because it costs so much less than hydrogen. In cylinders, less than half as much. In bulk, about one-fourth!

When you're saving as much as $10.00 per 1,000 c.f. of atmosphere, you soon recover the cost of a dissociator. Then, too, consider the safety and storage factors. With ammonia, the only flammable gas present is the gas you're *using*. Ammonia storage equipment does not present a flammable safety hazard.

Dryness of the atmosphere is important, too. With dissociated ammonia, a dew point of —60°F. can be obtained without drying equipment.

Why Armour?

Says Sonotone's maintenance supervisor, Jack Richardson: "We know from ten years' experience that we can depend on the high purity and uniform quality of Armour ammonia. Also, we know we can count on Armour's expert technical service."

When you buy Armour ammonia, you have no doubts about purity. Every cylinder, every tank truck is tested, *after filling*, to make sure the ammonia is at least 99.98% pure when delivered.

Another advantage: Fast delivery from 171 distribution points across the country. See your Yellow Pages for the stock point nearest you.

AMMONIA SALES: Cylinder, Tank Truck, Transport and Tank Car Service

Armour Industrial Chemical Company

One of The Armour Chemical Industries

110 North Wacker Drive • Chicago 6, Illinois

The ASM is the communications center for technical information wherever metals are produced, processed, fabricated, designed, tested and applied. Metal Progress, monthly engineering magazine of the Society, reports on engineering developments in these 11 major technological areas:

FERROUS METALS

NONFERROUS METALS

HEAT- AND CORROSION-RESISTANT AND ELECTRICAL MATERIALS

RADIATION AND NUCLEAR MATERIALS & EQUIPMENT

TOOL MATERIALS, CUTTING AND FORMING EQUIPMENT

INDUSTRIAL HEATING EQUIPMENT AND SUPPLIES

CLEANING AND FINISHING EQUIPMENT AND SUPPLIES

WELDING AND JOINING EQUIPMENT AND SUPPLIES

INSPECTION AND CONTROL EQUIPMENT AND SUPPLIES

PRODUCTION AND CASTING EQUIPMENT AND SUPPLIES

PARTS, FORMS AND SHAPES FOR DESIGN AND APPLICATIONS

FIRST CLASS
PERMIT NO. 146
ST. JOSEPH, MICH.

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July, 1961 issue
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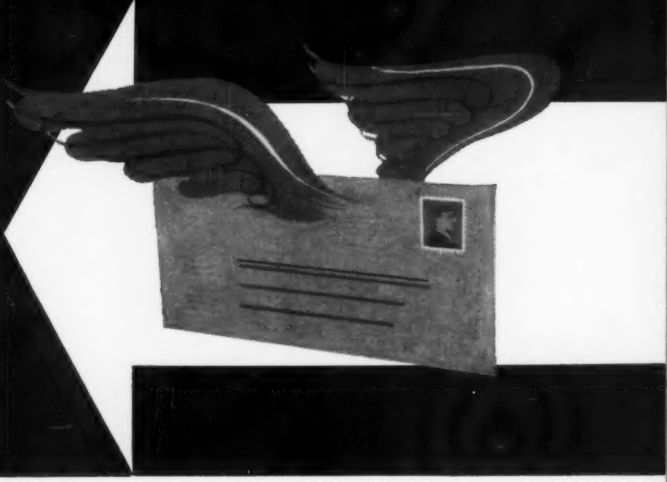
Complete Reader Service Information With These Convenient Prepaid Cards



Catalogs and bulletins, new products and services and most advertisements in Metal Progress are numbered. To receive more information, circle the appropriate numbers on one of these postage paid cards. Editorial reprints will be sent free as long as they last.

Catalogs and Bulletins are available from a *scrutinized* and up-to-date list of manufacturers' literature, conveniently indexed under the 11 major Engineering Areas.

More Facts on Advertised Products. Because some advertisements cannot be numbered, please write the names of those advertisers in the blanks provided.

New Products and Services are numbered. Circle the postcard for more information.

Reprints of Articles are yours for the asking as long as they last. No need to clip your Metal Progress issue for reference filing; send for reprints.

Please Include Your Name and Address!

Metal Progress July, 1961 issue

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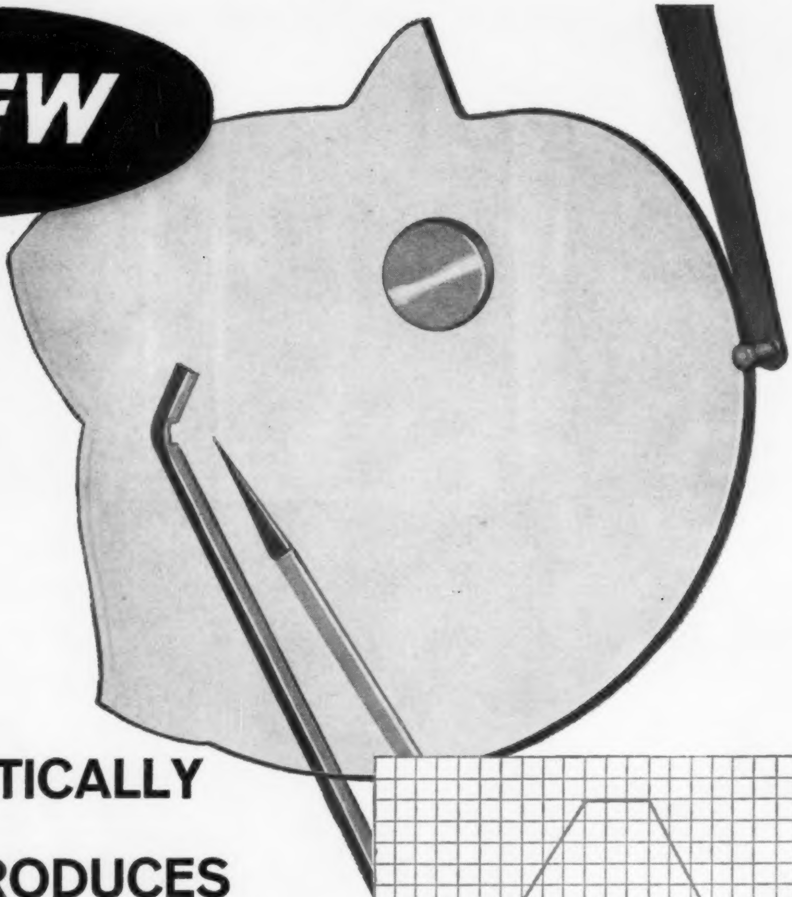
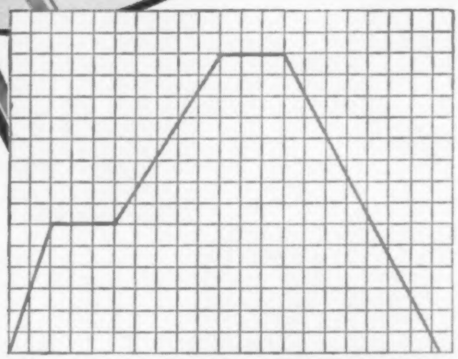
NEW

... through research by Barber-Colman



IDENTICALLY REPRODUCES PROGRAMS WITH THE FAMED "ELECTRONIC LINK"



Typical program includes 2 rise, 2 soak, and a cooling period.

The Series 2000 Cam-Operated Program Controller raises new standards in quality control. The metalworking, ceramic, and glass industries can now process batch after batch and get precise reproduction of time and temperature cycles. Wheelco's "Electronic Link" transmits cam contour to an electronic null-balance controller. Cams are easily and accurately cut in the field! Write for Bulletin F-10191 or call Barber-Colman.

BARBER COLMAN

BARBER-COLMAN COMPANY

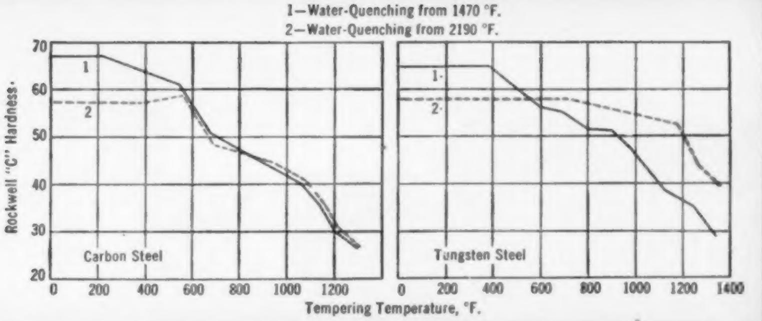
Wheelco Industrial Instruments Division

Dept. S, 1518 Rock Street, Rockford, Illinois, U.S.A.

BARBER-COLMAN of CANADA, Ltd., Dept. S, Toronto & Montreal • Export Agent: Ad. Auriema, Inc., N.Y.

Circle 429 on Page 48-B

Increase of Stability of Hardness Upon Tempering Tungsten Steel Because of Increase in Quenching Temperature. Note absence of this phenomenon in plain carbon steel.



ONLY Tungsten

meets these rigid tool steel requirements

For the severest requirements of cutting tools, whether in Tungsten carbide or in high-speed steel, Tungsten is indispensable. There are also other important uses in which hot-working steels and high-temperature steels owe their superiority to the presence of Tungsten.

Useful qualities that can be imparted to carbon steels by the addition of Tungsten are greater toughness at a given hardness, greater resistance to corrosion at a given hardness, and better sustained hardness at high temperatures. Stability of hardness, in particular, is indicated by the chart here reproduced. This chart and others, with a thorough discussion of the most economical and most successful uses of Tungsten, will be found in a book, "Tungsten Steel," which may be had on request.

Inquiries on any contemplated use of Tungsten, Molybdenum, Rare Earths, Columbium, or Boron will be welcomed.

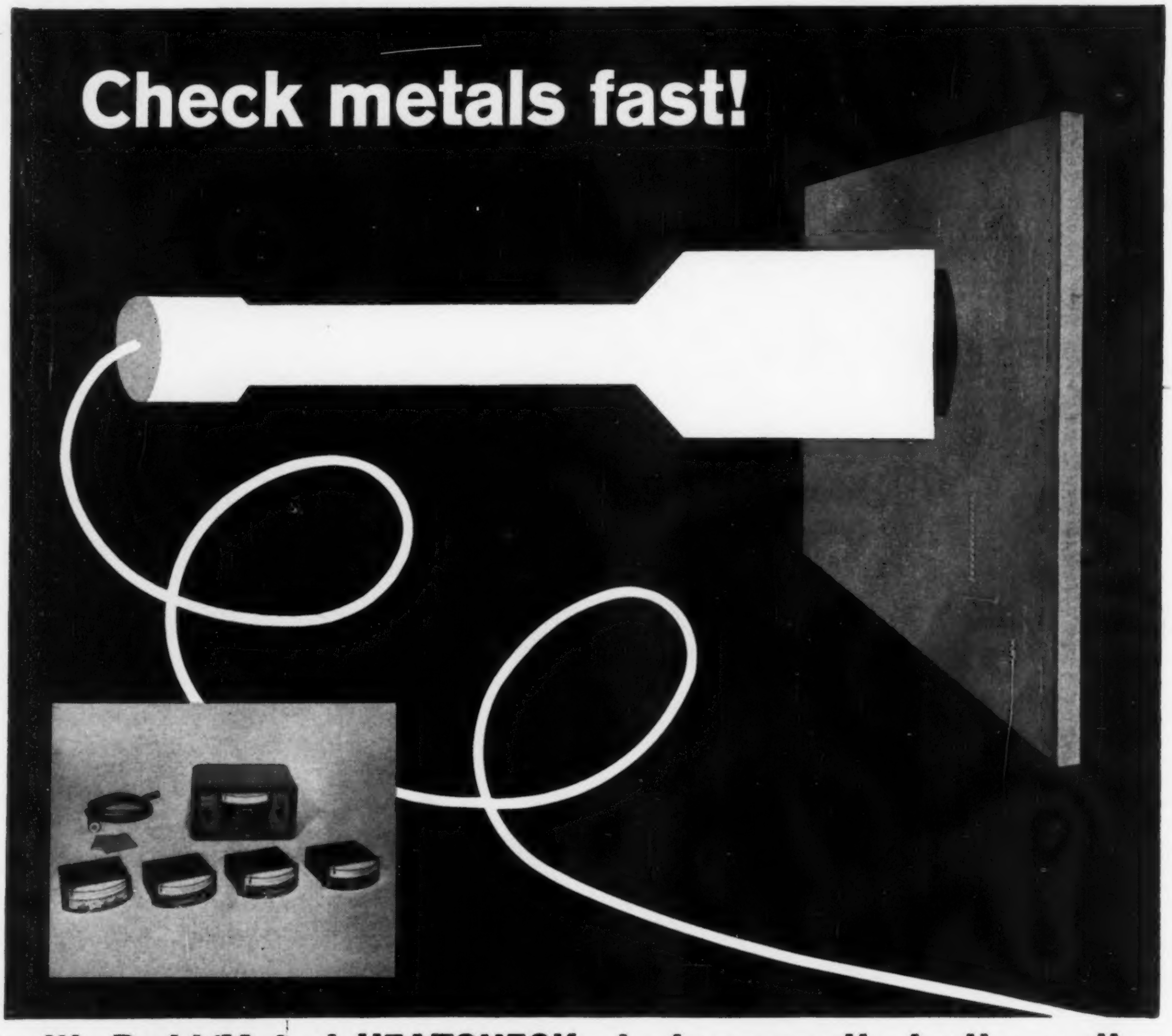
MOLYBDENUM

CORPORATION OF AMERICA

1312, Building Number 4, Gateway Center, Pittsburgh 22, Pa.

Offices: Pittsburgh, Chicago, Los Angeles, New York, San Francisco
Sales Representatives: Brumley-Donaldson Co., Los Angeles, San Francisco
Subsidiary: Cleveland-Tungsten, Inc., Cleveland
Plants: Washington, Pa., York, Pa.

Circle 430 on Page 48-B



with Budd/Metrol HEATCHECK electromagnetic testing units

In a matter of seconds, the Budd/Metrol Heatcheck identifies alloys and heat treat conditions of both ferrous and non-ferrous metals . . . detects parts that don't meet specifications for heat treatment, hardness, strength, composition or purity . . . checks for carburization . . . measures thickness of non-ferromagnetic platings, foils and insulating coatings . . . detects areas overheated in manufacture or by an in-service fire . . . supplies your metallurgical laboratory with information about metal structure impossible to get in any other way.

Measurements are made nondestructively by placing the Heatcheck probe on the surface to be inspected. Results are displayed on a divided scale. Operation is simple, yet the Heatcheck is a highly sensitive eddy current instrument that detects slight hardness differences of a few points Rockwell. Completely transistorized and battery operated, the Heatcheck weighs only 5½ lbs., goes handily anywhere in shop, field, lab or production line.

Write for full information or a demonstration of the Budd/Metrol Heatcheck in your own shop.

INSTRUMENTS Budd DIVISION

THE BUDD COMPANY • P.O. Box 245 • Phoenixville, Pa.

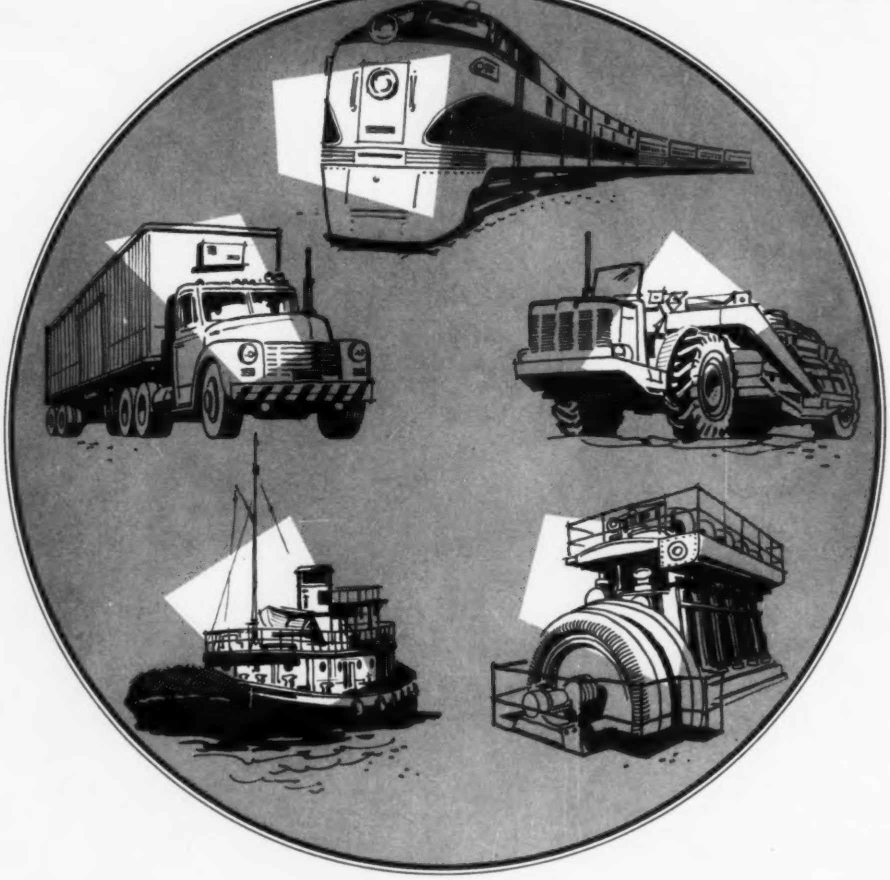
Consult your phone book for sales offices in: Atlanta, Ga.; Oak Park, Ill.; Detroit, Mich.; Seattle, Wash.; Dallas, Texas; San Francisco, Calif.

In Canada: Budd Instruments, Ltd., 170 Donway West, Don Mills, Ont.

Other countries: Budd S.A., 10 Avenue de la Grande Armée, Paris 17e, France.

Circle 431 on Page 48-B


Ideas in
metallurgy
from Norton



Feedlines for hungry horsepower . . . diesel fuel injection tubing by Superior

Fuel injection systems are the heart of thousands of diesel-powered trucks, locomotives, roadbuilding equipment, electric generators, and marine power plants. The tubing that conveys the fuel from injection pump to nozzle assembly is an important component. It must resist the stresses of pressure and vibration, yet be ductile enough to be cold swaged and upset and be cold formed into loops and bends without excessive springback. It must have a clean ID, tremendous burst strength, and high fatigue resistance. Superior diesel fuel injection tubing is just such a premium product.

Type C-1008 and Type MT-1010 carbon steel tubing are most commonly specified for this application, but alloy and stainless steel tubing for pressures above 9000 psi and greater corrosion resistance is available. Superior also makes tubing for many other applications—supplies both general and special purpose tubing for aircraft, missiles, electrical, electronic, chemical, hydraulic, dairy and nuclear, to name a few. For complete information, write Superior Tube Company, 2008 Germantown Ave., Norristown, Pa.

SOME REASONS WHY SUPERIOR FUEL INJECTION TUBING IS A PREMIUM PRODUCT

- It will handle pressures to 9000 psi, is hydrostatically tested to various pressures according to specification
- It is cold drawn, dead soft annealed, and seamless
- It is ID conditioned to remove fissures and other defects
- It is free from ID radial cracks deeper than .005 in. or 5% of wall thickness, whichever is less
- It is annealed at finish in controlled atmosphere furnaces to produce a soft, ductile and scalefree material
- Fracture tests are performed when requested

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

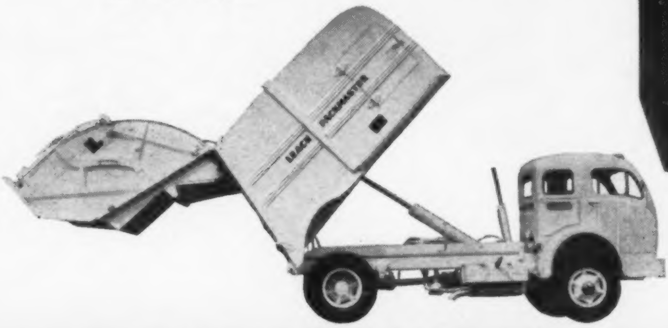
All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

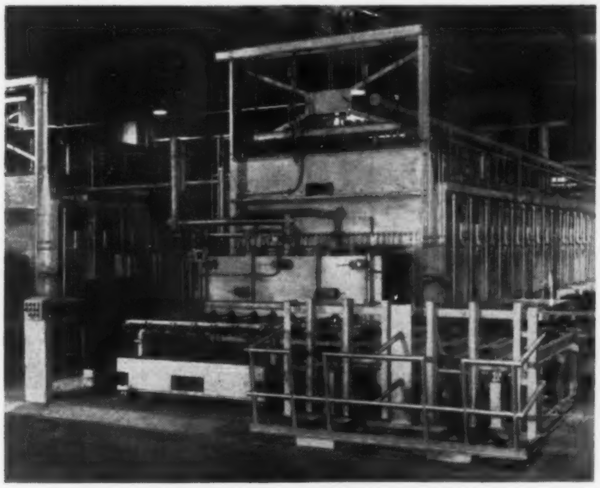
West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

Circle 433 on Page 48-B

Circle 434 on Page 48-B

COLD FINISHED ALLOY BARS form high strength pins to carry the full weight (up to 5 tons) of this Packmaster body and its refuse load when unit is hoisted to unload. Republic Cold Finished Alloy Bars, cut off, drilled, and chamfered by Leach Company, Oshkosh, Wisconsin, manufacturers of the Packmaster, offer the toughness and abrasion resistance necessary in this application. Investigate the advantages of using Republic Cold Finished Alloy Bars for your component parts production. Mail coupon.





NEW ANNEALING FURNACES provide maximum heat treating capacity for cold extrusion steel. Quality of steel produced at the Chicago Bar Mill attains a high level of uniformity through heat treatment in two new atmosphere-controlled annealing furnaces. These new furnaces provide the capacity to assure prompt delivery of orders for heat treated steels.

BENDING, FLANGING, SEAMING—ductile zinc coating on Republic Galvannealed Sheets stays tight, resists flaking, peeling, or spalling. Hot dip galvanizing plus special heat treatment give Galvannealed a graduated coating of iron—zinc alloys between the pure zinc outer surface and the base metal. The tough, uniform protective finish that is spangle-free provides a good paint base, withstands temperatures to 750°.

REPUBLIC

REPUBLIC STEEL

REPUBLIC HAS THE FEEL FOR MODERN STEEL

Strong, Modern, Dependable

Steel

Circle 435 on Page 48-B

REPUBLIC STEEL CORPORATION
DEPT.MP-2199
1441 REPUBLIC BUILDING • CLEVELAND 1, OHIO

Please send me more information on the following products:

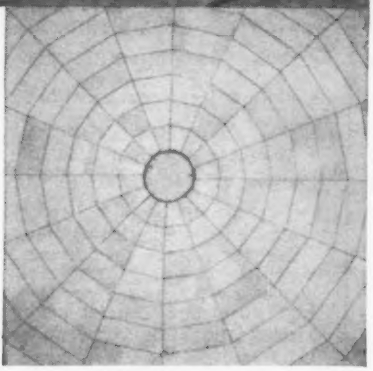
- ☐ Republic ELECTRUNITE® Mechanical Tubing
- ☐ Republic Steel for Cold Extrusions
- ☐ Republic Cold Alloy Bars
- ☐ Republic Galvannealed Sheets

Name__________ Title__________

Company__________

Address__________

City__________ Zone____ State______



Inside Looking Up...*view from below the dome of a Lee Wilson bell-type furnace. Note close fitting between Superex blocks. This dome actually supports installation workers' weight* ... without use of cement!

ONLY J-M SUPEREX BLOCK INSULATION GIVES YOU ALL THESE ADVANTAGES:

High Compressive Strength—only ⅛" compression under 85 lbs psi

Low Conductivity—.82 at 1000F mean temperature

Low Heat Shrinkage—2.7% linear shrinkage at 1900F

Large Size Blocks—12" x 36" blocks speed application, reduce number of joints. Yet blocks are light in weight for ease of installation

Lightweight—only 24 lbs per cubic foot

JOHNS-MANVILLE

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Circle 436 on Page 48-B

How to braze 28 parts of one assembly at one time

The objects shown above are the individual parts and the final brazed assembly of a solid copper, vapor-cooled anode used in a 400 kw continuous output triode. It's produced by the Machlett Laboratories, Springdale, Conn. There are 28 parts in all and the assembled unit weighs 85 lbs. A total of 51 areas and 20 feet of surface must be brazed in one operation. Strong, uniform, vacuum-tight joints are essential.

A Harper pusher-type box furnace equipped with vertical GLOBAR® silicon carbide electric heating elements does the job. Brazing is done in a hydrogen atmosphere protected by purging chambers using nitrogen and hydrogen. Operation is continuous—24 hours a day.

GLOBAR elements make possible the precise control—at 2200 F—necessary for this critical operation. They offer the advantage of clean heat, independent of the atmosphere. The rod type elements simplify furnace design. Maintenance requirements are small—furnace refractory has been changed only once in 4 years, indicating the mild conditions to which brick is subjected with this type of heating. Heat loss is so low that working areas are located immediately adjacent to the furnace.

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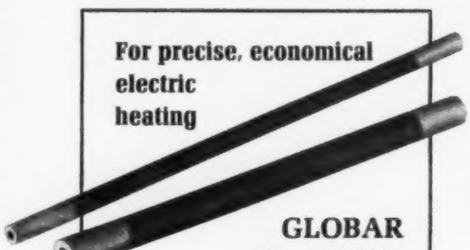

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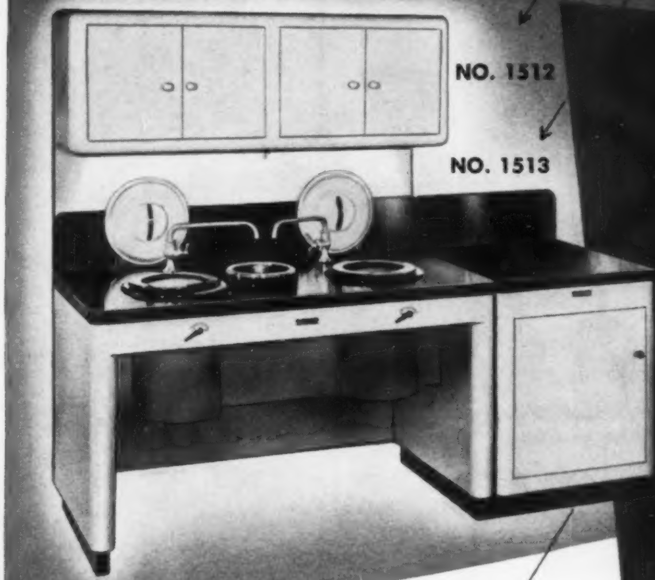

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...with matching storage cabinet...

For maximum efficiency in the production of specimens in the metallurgical laboratory the Buehler cabinet type polishing table with companion storage cabinets represents the latest modern development of this type of equipment.

The convenience of this streamlined polishing equipment saves time and encourages the operator to produce the highest quality of polished sample.

Item No. 1511 is a two-unit polishing table with Formica top approximately 60" long x 27" deep x 30" high to table top. Two 12" swing spouts, drain, 8" diameter wash bowl, plumbing, and wiring.

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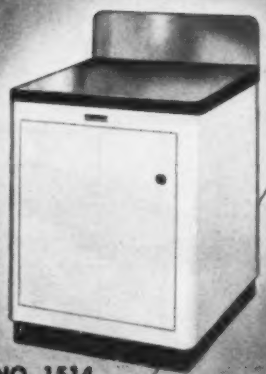

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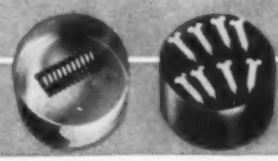

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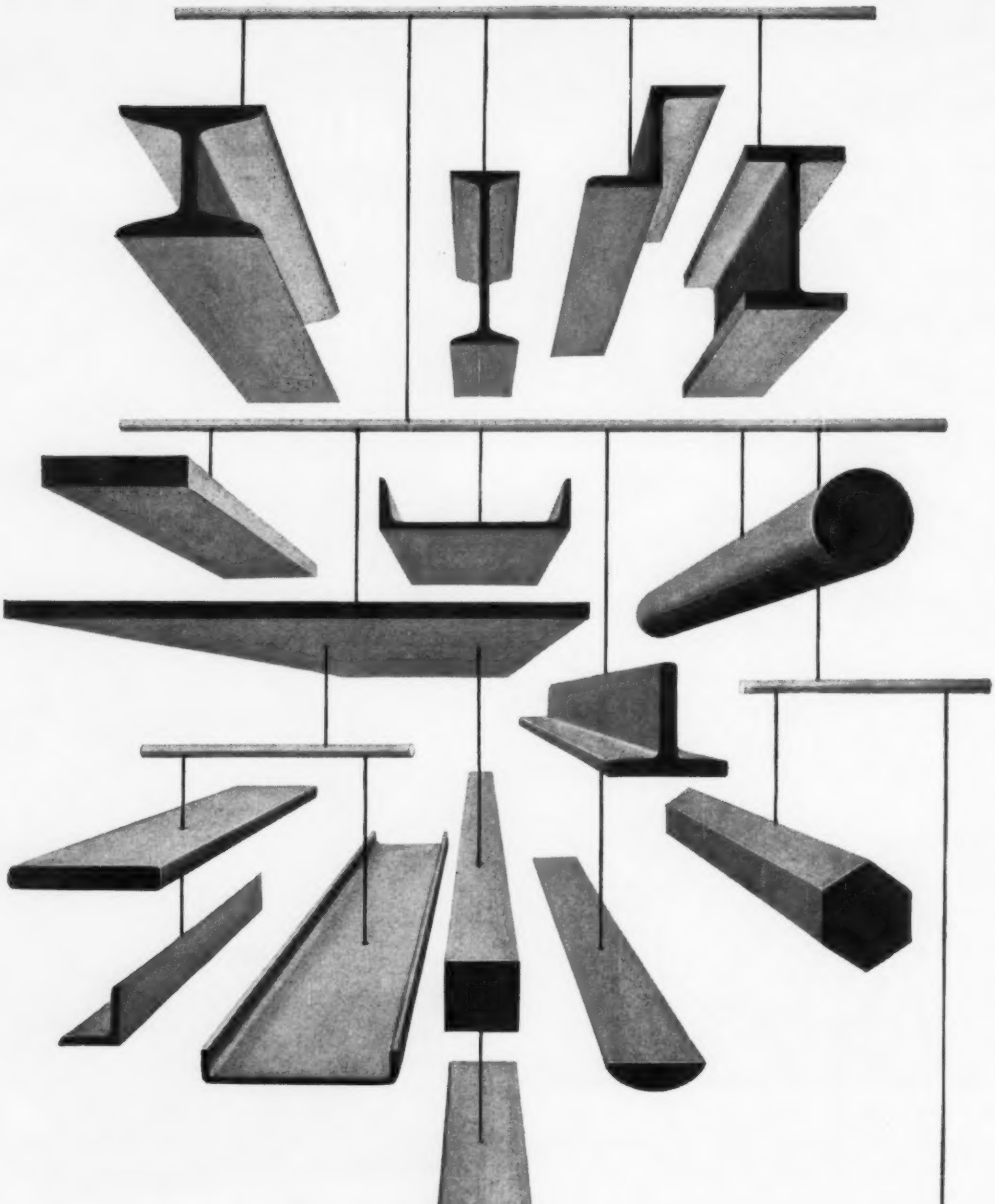

Circle 441 on Page 48-B

METAL PROGRESS

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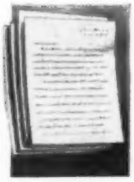


Critical Points

By the EDITORS

Are You Becoming Obsolete?

THIS MAY SOUND like a startling question to ask a technical man, yet it could be asked of some highly competent, but unlucky, engineers in this country. Just as skilled workers have been shelved by automation of complex routines, these men have been replaced by computers that can solve equations at rates many times those achieved by the most accomplished mathematicians. In this particular situation, which is reported in "Education for Oblivion?", an article by Thomas Stelson published in *Carnegie Alumnus*, highly trained mechanical engineers were engaged in calculating optimum designs for gear trains, a complex operation which often required one-half day for manual solution.

Yet, when a computer was programed for such problems, the machine determined, along with the answers, the time charge and billed the appropriate department – for the *minimum* charge, 42 cents. And, as Dr. Stelson thoughtfully continued, "What industry wants to, or should, resist the pressure to replace a \$40-a-day engineer with an 84-cent computer bill?"

Admittedly, this is an extreme example. Yet, it points up the rapid and continuing progress in engineering today. The speed of expanding technology, in fact, is such that any technical man, no matter how able, must continue to grow and develop as his field grows and develops. Otherwise, he will be left behind while younger men who have received a more recent and up-to-date education will pass him by.

In civil engineering, for example – as head of the civil engineering department at Carnegie Tech, Dr. Stelson is particularly conversant with that field – the undergraduate curriculum has changed about 25% in the last ten years, outdated courses having been replaced by more advanced work in science, mathematics and engineering. In the B.S. degree program, new knowledge increases at the fantastic rate of 10% a year, according to Dr. Stelson. Thus a graduate of ten years ago, unless he has systematically spent about 10% of his time increasing his knowledge beyond the level achieved in his now outmoded college work, will not be worth as much as a new graduate.

To make matters even more critical, the foregoing analysis assumes that this engineer has retained all of his previous training. And how often does this happen? It is far more realistic to allow for a rate of decay from neglect or disuse, and thus plan to spend even more time on personal advancement. In fact, according to Dr. Stelson, if he also wishes to increase in value

to his profession, he ought to devote as much as one third of his time to self-education and improvement.

There are other signs that the technical man in today's industry must travel at an ever-increasing pace to stay with his field. In a recent address to a meeting of the American Chemical Society, E. V. Murphree, president of Esso Research and Engineering Co., reported that, in 1960, over $12 billion was spent on research and development in the United States alone. The staggering increase in knowledge which results from such colossal expenditures, while it may be of academic interest, can only be of value if it is put to proper use. However, it seems evident that this will happen – some estimates place the 1970 research outlay at $20 to $25 billion every year.

To give you an idea of what can be accomplished by such awesome amounts of money, consider these figures. In 1959 *Chemical Abstracts* consisted of seven volumes which contained nearly 130,000 abstracts. (The *Review of Metal Literature* added 12,000 abstracts of its own.) There were 60,000 scientific, technical, and trade journals published throughout the world. The libraries of the world made room for 1800 new technical books. Remember, this happened two years ago! In 1970, with the continuing emphasis and greater expenditure on research, even these astronomical publication figures can easily be doubled! Think of the amount of knowledge that the future graduate will be expected to absorb merely to get his degree.

But that's only the beginning. He will need to add constantly to this "basic" background throughout his professional life. In the meantime, what will you be doing? Even though you may be a student now, in ten years you will be in the profession, and much of the knowledge you are now gathering will have become obsolete. Sobering thought, isn't it? As for those of you already in the profession, your problems in staying abreast in your field will be compounded by this constant accumulation of new knowledge.

Under such circumstances, it would not be surprising if you began to feel like Alice and the Red Queen in *Through the Looking Glass*, who had to run at top speed merely to stay in the same place. And, as the Red Queen remarked later, "If you want to get somewhere else, you must run at least twice as fast as that!"

It is quite evident that the technical man can not stop learning when he is handed his diploma. And if he is worth his salt, he already knows this. The question is, how is he to make the best use of his time, a commodity which seems to be getting more limited, and consequently more valuable all the time. As an answer, Mr. Murphree remarks, "The perceptive individual quickly learns to be an omnivorous but selective reader. He learns the mechanics of gathering information – that is, where to obtain facts, whom to ask for specialized knowledge, what technical meetings are most productive for him, what facilities for advanced studies are available, and the like. Finally he seeks to widen his acquaintance among the people doing technical work, particularly in different fields." In short, the engineer who wants to grow and progress in his chosen profession should read extensively, continue with his education in any way possible, and partake of the knowledge of his technical colleagues.

While his actual course of action is entirely up to him, he can do these things through membership and active participation in technical societies. For example, the A.S.M. sponsors local, regional, and national technical meetings, publishes technical journals and books, operates a documentation service, and offers home study courses in virtually every area of metallurgy and related fields through its division, the Metals Engineering Institute. Through the use of any or all of these facilities, the technical man can better his professional standing.

We will conclude this dissertation with two quotations, both of which any engineer would do well to remember. They sum up the whole situation much better than anything we might say. First, Mr. Murphree again: "It is not too old-fashioned or unreasonable, I think, to expect a technical man to be dedicated to his profession. He has inherited the wealth of past scientific accomplishments, and he cannot take his responsibilities to his scientific ancestors – or to his heirs – lightly."

And, finally, let the late Charles Kettering speak: "So many men are looking for park benches along the road where they can sit and rest. But the only park benches I know of are immediately in front of the undertaker's place. There is no spot in an industrial situation where you can sit down and rest. It is a question of change, change, change all the time. And it's always going to be that way."

Staff Report

Forming and Finishing Aluminum Auto Trim

Though simple in concept, the bright anodizing process – electrolytic oxidation of aluminum – requires close control of all operations from incoming inspection through final sealing to produce trim that will stand up in the severe service environment encountered by most automobiles. (L19, G4, T21c; Al)

Increased use of aluminum for automobile trim has come not only as a result of alloy development but also because of progress in forming and bright anodizing on a production basis. To find out what techniques are being employed to produce bright trim, the editors of *Metal Progress* visited engineers and production men at Eaton Mfg. Co., which has converted part of its Stamping Div. in Cleveland from the production of chromium-plated steel to bright anodized aluminum.

Careful Process Control

As in any metalworking plant, the key to high quality lies in careful process control from one end of the line to the other. Engineers at Eaton have set up a thorough inspection system which goes into operation as soon as incoming blanks of 5357 or 5457 alloy sheet arrive from the rolling mills. The thickness of the blanks, which ranges from 0.035 to 0.090 in., is checked and tests are made to determine if each piece has been tempered properly. Annealed sheet is used for the more difficult forming operations, but sheet in the H 25 condition* is preferred because it develops a brighter finish after anodizing. Sheet finish may be specified "one-side-bright" or mill-finish; most trim is made from the latter. A thorough visual inspection for handling marks is made because deep scratches may not be eliminated in subsequent buffing or bright dip operations.

Forming and Buffing

Depending on size and part configuration, blanks are sent to presses ranging in size from 110 to 600 tons. The blank for the 1961 Ford grill, for example, is shallow drawn on a 400-ton press (Fig. 1), pierced on a second 400-ton

The editors wish to acknowledge the assistance of J. P. Coros, chief chemist, Stamping Div., Eaton Mfg. Co., Cleveland.

*The H2 designation means that the sheet has been cold rolled to the full-hard temper and then partially annealed to an intermediate level of properties. The second digit indicates degree of hardness (H22 is ¼-hard; H28 is full-hard).

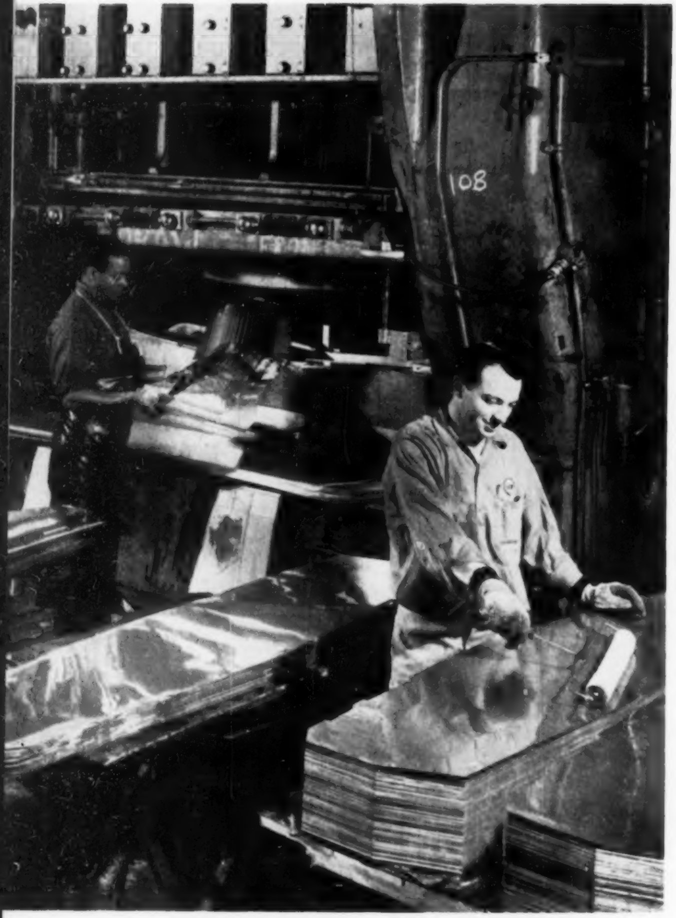


Fig. 1 — Aluminum Blanks Are Formed Into Grills in a Series of Stamping Presses. Drawing compound being applied by roller is a mixture of kerosene and light oil

press, and then finish-formed and trimmed on two three-stage, 600-ton presses. Press tools must be kept sharp and some are plated with chromium to reduce wear. The only drawing lubricant used is a commercial mixture* of kerosene and light oil.

After being formed, parts are inspected for marks and tears and for correct contour and fit on grills and bezels. They are then buffed on automatic or semiautomatic equipment. The grills, generally processed on an Acme straight-line buffing machine (Fig. 2), are backed up by close-fitting adapters made of fiberglas castings which prevent bending during the buffing operation.

The Anodizing Process

There are four major operations involved in anodizing — cleaning, chemical polishing, anodizing, and sealing. All steps are important and must be closely controlled if satisfactory auto trim parts are to be produced.

The cleaning of buffed or unbuffed aluminum must be done in such a way that contamination of the bright dip and anodizing solutions is prevented. The cleaning line, which is part of the Hanson-Van Winkle-Munning automatic anodizing setup sketched in Fig. 3, consists of a soak cleaner which loosens the buffing compound, a warm-water jet-spray rinse, another soak cleaner which saponifies the drawing lubricant, a cold-water rinse, and a nitric-acid dip (at room temperature) which neutralizes alkali from the previous soak cleaner and prepares the base metal for the next operation. Soak clean-

*Made by Macco Products Co., Chicago.

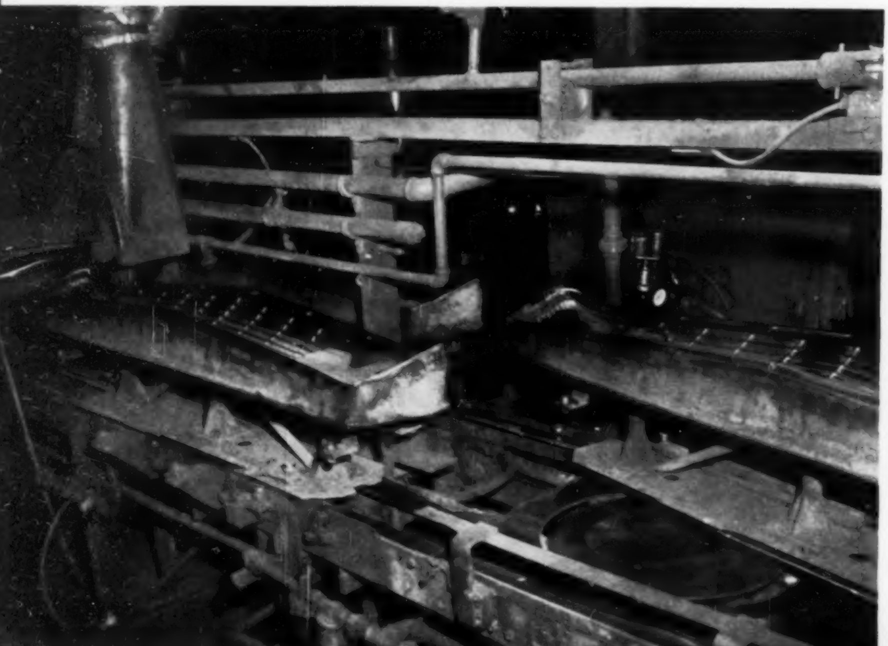


Fig. 2 — Grills Are Polished on an Acme Automatic Buffing Machine Prior to Anodizing. Note close-fitting fiberglas backups, which prevent bending

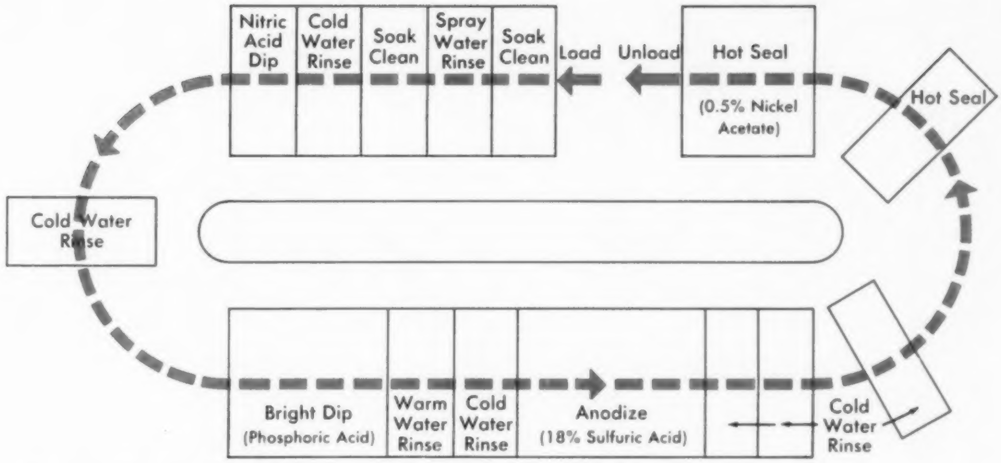


Fig. 3 — Floor Plan of Automatic Anodizing Machine. Anodizing sequence involves thorough cleaning, bright dip anodizing, and sealing. Parts travel on a variable-speed, elevator-type conveyor with horizontal carrier arms

ers are standard commercial compounds made specifically for cleaning aluminum.

Chemical Polishing

After a cold-water rinse, parts are immersed in the bright-dip tank (Fig. 4). Best results are obtained with a bright-dip treatment of 1½ to 2 min.* Customer specifications require a high degree of luster, akin to a buffed nickel surface on auto trim. This demands extremely close control of the bright-dip solution. Phosphoric acid concentration, temperature, water content, and solution levels are checked hourly. Solution temperature is maintained between 180 and 190° F. by automatic control instruments. Agitation, provided by low-pressure filtered air, is checked hourly and air lines are flushed out with water at weekly intervals.

In operation, the bright-dip solution will experience an increase in aluminum content. However, equilibrium is soon reached, since as much dissolved aluminum is dragged out as is introduced. With careful control of water and aluminum content, there appears to be no reason why the bright-dip solution cannot be used indefinitely.

Anodizing Control Is Critical

To prevent carry-over of phosphate from the bright-dip tank, all parts are thoroughly rinsed

*The process is patented by Alchemize Co., Chicago.

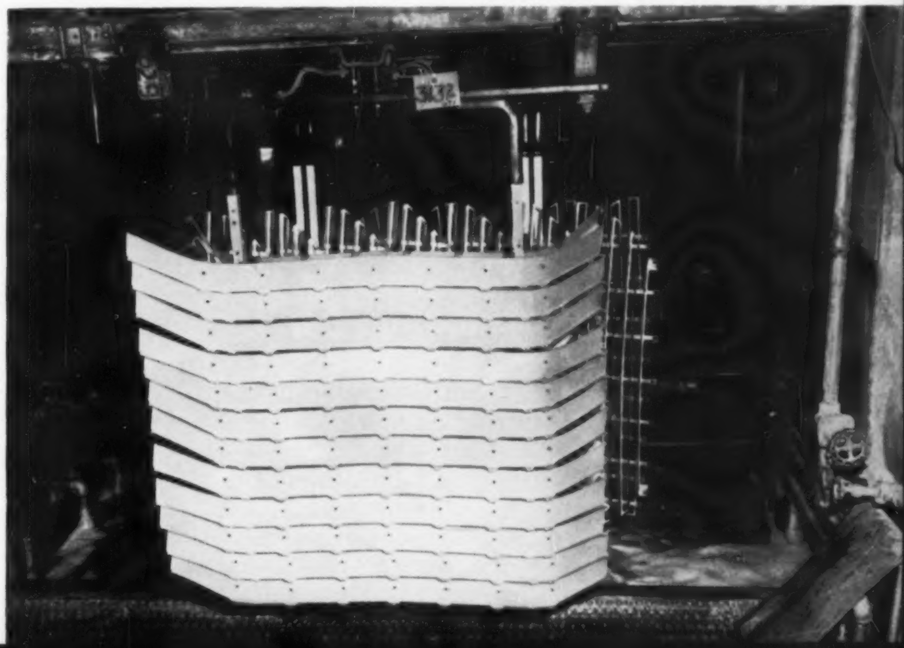


Fig. 4 — Close Control of the Chemical Polishing (Bright Dip) Operation Insures Best Results. Parts shown are 1961 Chrysler grill frames

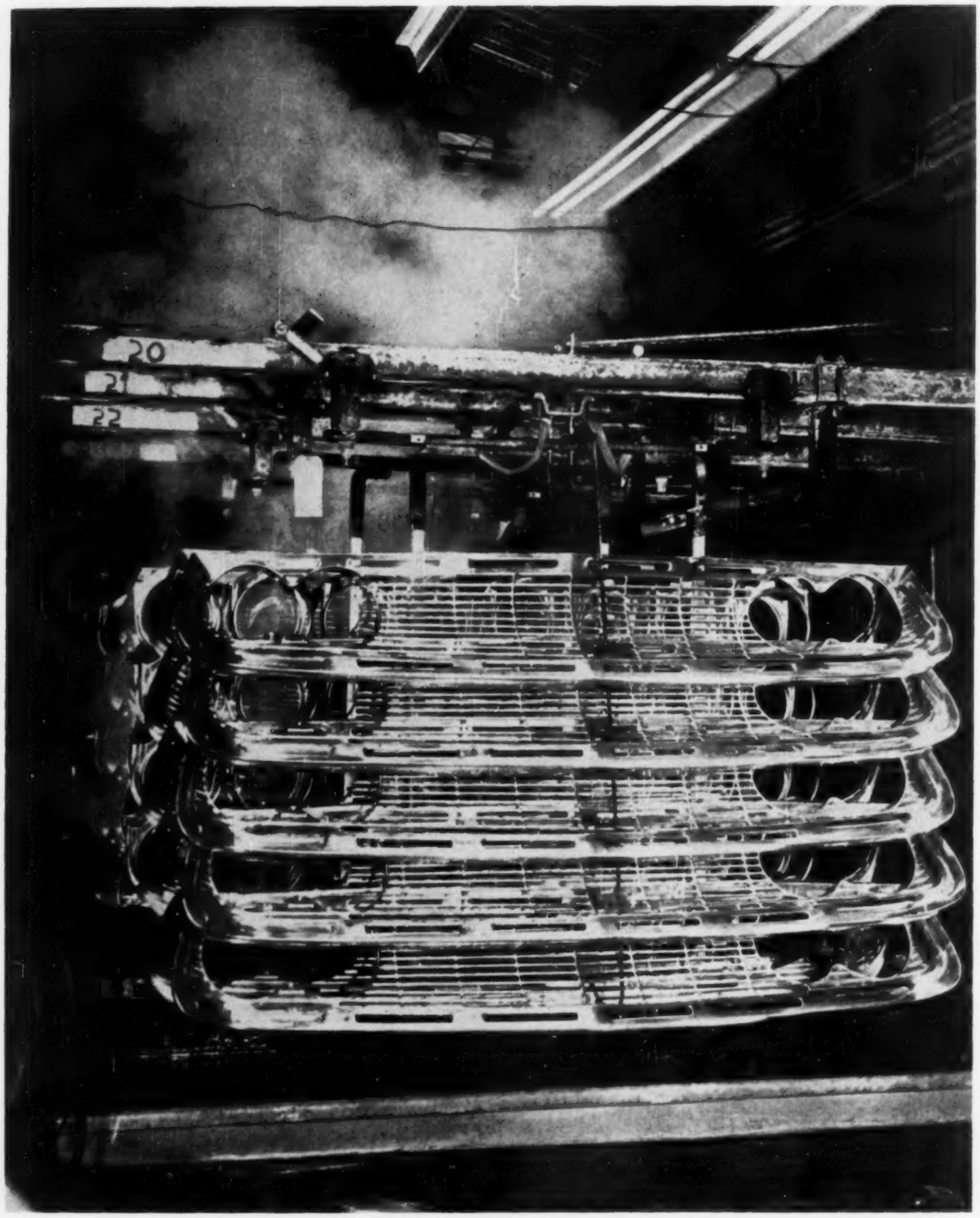


Fig. 5 – Racks Containing Grills for 1961 Dodges Are Lifted From the Anodizing Tank

prior to immersion in the anodizing solution (Fig. 5). In anodizing, the product to be coated (the anode) is dipped into an electrolyte and direct current (12 amp. per sq.ft.; 15 to 22 v.) is passed until an oxide coating is formed. The electrolyte, an 18% sulfuric acid solution, is maintained between 68 and 72° F.

As in the bright-dip solution, filtered air is used to agitate the bath. This is essential for producing a uniform, dense coating. (Electrolytic oxidation is an exothermic reaction; heat generated at the part surface must be quickly removed if a sound anodized film is to be produced.) Racks are designed to prevent light parts from falling into the electrolyte. Electrical contacts are made of titanium to maintain consistent, accurate current densities and extend operating life.

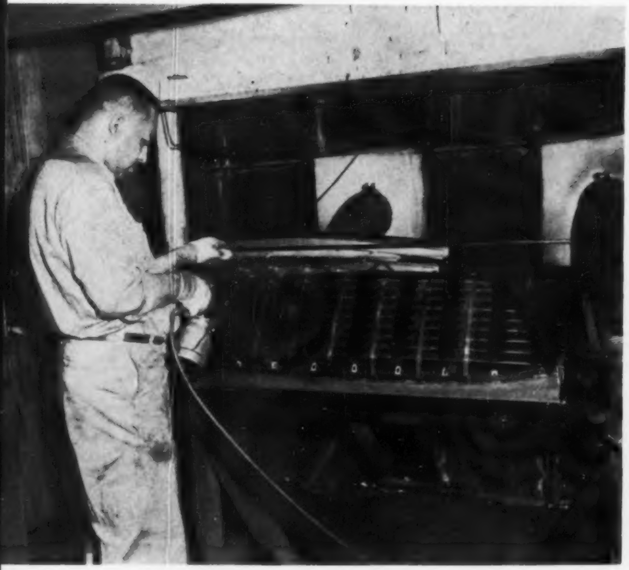


Fig. 6 – Support Webs on Grills Are "Blacked-Out" by Spray Painting. Baking at 225 to 250° F. for 30 min. follows

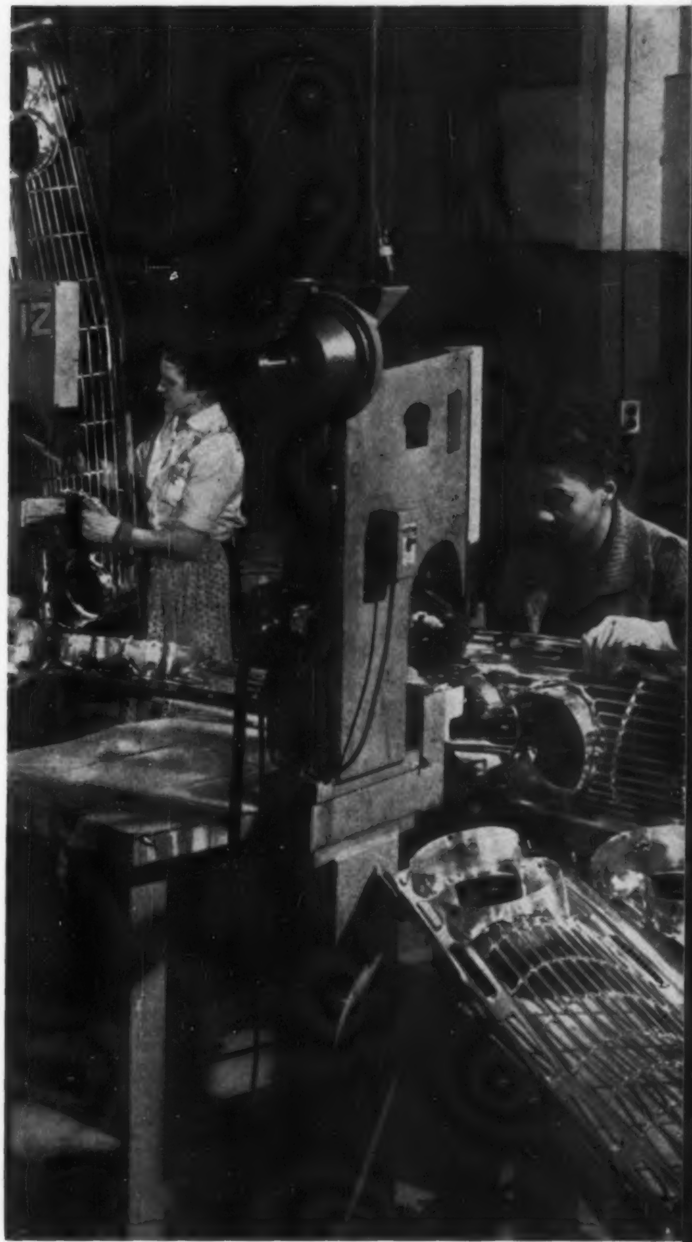
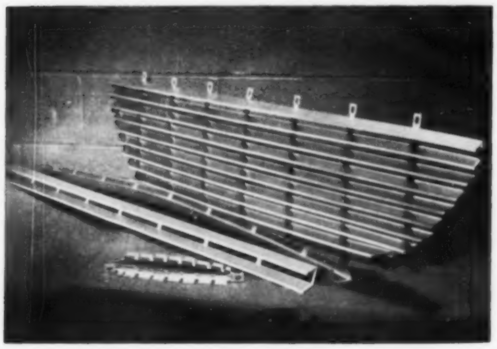


Fig. 7 – In Final Assembly, Headlamp Bezels Are Riveted to the Grills

Fig. 8 – The 1961 Chrysler Grill Is an Assembly of Several 6463 Extrusions and Clips. Each rib is etched, then its front face is buffed before anodizing



The condition of the electrolyte is checked, recorded, and corrected every hour (rather than once per shift) to prevent radical changes in the composition of the solution.

Sealing the Anodized Film

The anodizing process builds up a porous oxide surface on aluminum. To provide good corrosion resistance, parts must be rinsed thoroughly – to remove all contamination – and then completely sealed in a 0.5% solution of nickel acetate and deionized water maintained at 210 to 212° F. Sealing is performed in stainless steel tanks for periods ranging from 2 to 10 min. Temperature and pH (5.0) are checked manually every hour. The efficiency of the sealing treatment is also checked hourly with Anthraquinone RN dye. A poor seal will retain

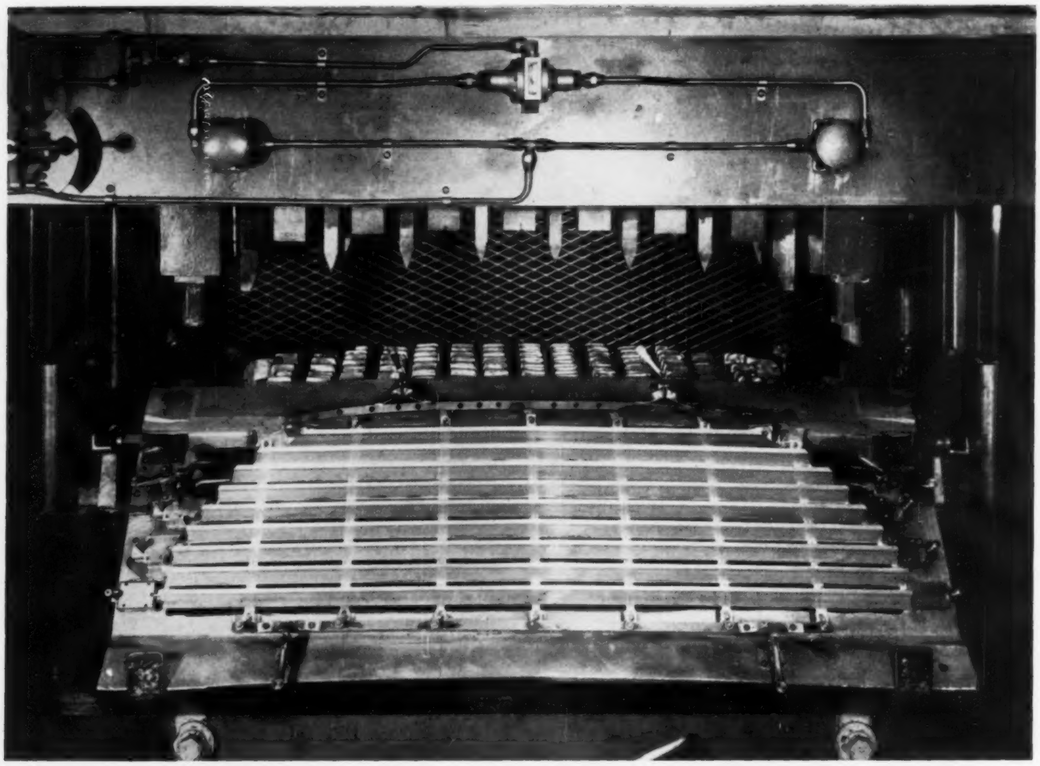


Fig. 9 – Special Crimping Machine Used in Assembling Extruded Parts Into 1961 Chrysler Grill

color after the dye is applied and rinsed off.

For automobile trim, the thickness of the anodized coating must be at least 0.0003 in. This is checked with a standard voltage-breakdown instrument ("Anodicator" made by R. O. Hull and Co., Inc., Cleveland) or a metallographic examination. Parts must also pass an accelerated corrosion test (5% salt spray for 240 hr.; A.S.T.M. designation B117ST) or other corrosion tests as specified by the customer.

Finishing Operations

Some parts such as grills are then sent to the painting room where certain support webs are "blacked out", as shown in Fig. 6. After being baked in a gas-fired convection oven at 225 to 250° F. for 30 min., the grills are inspected for marks, paint crazing, and anodized surface quality. Then in the assembly area, headlamp bezels and grills are joined by riveting (Fig. 7) using semitubular 5056 aluminum rivets.

Chrysler Grill

The grill on the 1961 Chrysler illustrates some interesting manufacturing concepts involving other aluminum alloys and nonstandard processing techniques. It is assembled from several 6463 extrusions and clips, as shown in Fig. 8. The extruded ribs are chemically etched in a 20% caustic solution, and then the front face of each rib is buffed. After assembly in a crimping machine (Fig. 9), the grill is sent through the regular clean-and-bright-dip sequence, but the time in each bath is shortened slightly; finally it is anodized and sealed by standard techniques. The contrast between the buffed and unbuffed anodized surfaces plus the unusual configuration achieved with extrusions produces a distinctive grill.

In theory at least, the anodizing operation is a relatively simple one, but engineers at Eaton point out that only by tight controls on every step of the process have they been able to maintain production of trim parts which will stand up in severe service environments. And since a trim part costs less to produce in anodized aluminum than in chromium-plated steel, they have under consideration further expansion of their automatic anodizing and other aluminum processing facilities.

Thermocouples for Ultrahigh Temperatures

*By J. C. LACHMAN**

Three new thermocouples have been devised for measuring temperatures in the 3000 to 5000° F. range. Of these, platinum-30% rhodium/platinum-6% rhodium and iridium/iridium-rhodium are useful to about 3700° F., and tungsten/tungsten-26% rhenium is useful to 4200° F. Better heat insulators are expected to increase the range of the latter combination to 5000° F. (X9q)

Recent developments in nuclear science and space technology have focused sharp attention on the need for accurate thermal sensing devices capable of operating reliably at 3000 to 5000° F. and even higher. Urgent demands for high-performance jet aircraft, missiles and rockets are forcing operating temperatures of power plants up and up. Existing prototype and proposed nuclear reactors have similar requirements. And, in research programs aimed at developing the advanced engineering materials and the ever more powerful fuels needed for such applications, accurate measurement of very high temperatures is also essential in determining physical properties and testing service capabilities.

To date, the conventional wire thermocouple has been the most widely used, most versatile, and most reliable method of obtaining accurate temperature measurements. The principal advantages offered by such thermal sensing elements are their compactness, ease of fabrication and installation, relatively low cost, rapid response to temperature fluctuations, ready adaptability to actuating controls, and potential usefulness over a wide range of temperatures.

However, the thermocouple materials in commercial use are limited by their melting points to temperatures well below those now seen as essential to the ultimate success of many nuclear and space projects. As a consequence, much research is being performed to find new thermocouple materials to meet such ultrahigh performance needs.

Two New Thermocouples

Recently, two new noble metal combinations for thermocouples have been found to hold considerable promise for certain applications involving temperatures over 3000° F. One of these is a modified version of the platinum-rhodium type; it employs alloys of platinum-30% rhodium versus platinum-6% rhodium. With the elimination of the pure platinum wire from the couple, the thermal-emf. stability is markedly improved. On the other hand, there is a considerable sacrifice of thermoelectric power.

The second noble metal thermocouple combines pure iridium with one of several iridium-rhodium alloys. (They can contain 40, 50, or 60% Rh.) Although the melting points of both materials exceed 4000° F., the maximum limit of the thermocouple will probably be at about 3700° F. in an oxidizing atmosphere.

Neither of these new thermocouples possess the ultrahigh temperature capability currently in demand, but they will both undoubtedly find extensive use in the intermediate temperature range. At present, the National Bureau of Standards, in conducting an extensive study of these materials, has reported progress in efforts to develop standard calibrations.

*Project Engineer, Hoskins Mfg. Co., Detroit.

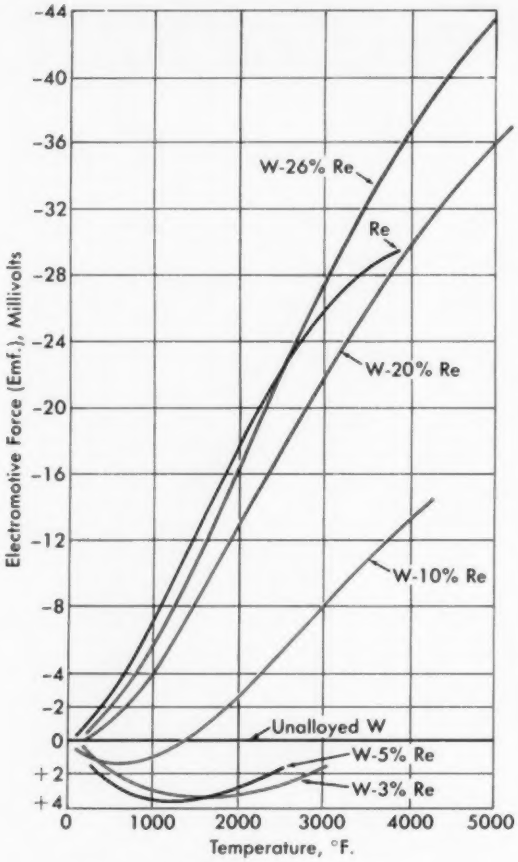


Fig. 1 – Thermal Electromotive Force of Tungsten-Rhenium Alloys and Pure Rhenium Relative to That of Pure Tungsten. These curves indicate that the tungsten/tungsten-26% rhenium combination gives the best results for thermocouples to be used at high temperatures

Thermocouples of Refractory Metals

To meet the requirement for measuring temperatures of 4000° F. and higher, the choice of materials for conventional wire thermocouples is limited to four refractory metals – tungsten (which melts at 6200° F.); rhenium (5800° F.); tantalum (5400° F.); and molybdenum (4800° F.).

The basic thermoelectric properties of the different combinations possible with these four unalloyed elements were first thoroughly evaluated by the Aircraft Nuclear Propulsion Dept. of General Electric Co. in 1956. From this work, G.E. engineers concluded that the tungsten-rhenium combination possessed the best thermoelectric properties at high temperatures. However, this combination also has two disadvantages: Thermoelectric power drops gradually as temperatures rise above 4000° F., and the ductile-brittle transition of pure tungsten results in poor mechanical stability.

In view of these factors, further research was concentrated primarily upon a study of tungsten alloys containing up to 30% Re. (Alloys with over 30% Re proved difficult to fabricate.) Figure 1, which gives the thermal emf. of tungsten-rhenium alloys relative to that of pure tungsten, shows that the thermoelectric power of this type of thermocouple becomes greater as the rhenium content of the alloy leg is increased. Accordingly, the researchers concluded that the tungsten/tungsten-26% rhenium combination would be the most desirable for ultrahigh temperature measurements. This thermocouple generates a high emf. which remains relatively linear up to at least 5000° F.

Although attempts to overcome the inherent brittleness of the pure tungsten were unsuccessful, extensive study has conclusively established that tungsten/tungsten-26% rhenium thermocouples can be employed up to 5400° F. Having a high thermoelectric power up to at least 5200° F., these couples would also be useful over a wide range of temperatures. As to their chemical and physical properties, the components are stable in nonoxidizing atmospheres, have relatively low vapor pressures, and can be fabricated into fine wires.

Fig. 2 – Special High-Temperature Furnaces for Sintering Powdered Refractory Metals and for Thermocouple Calibration Studies. They can be operated in the 4000 to 5000° F. range

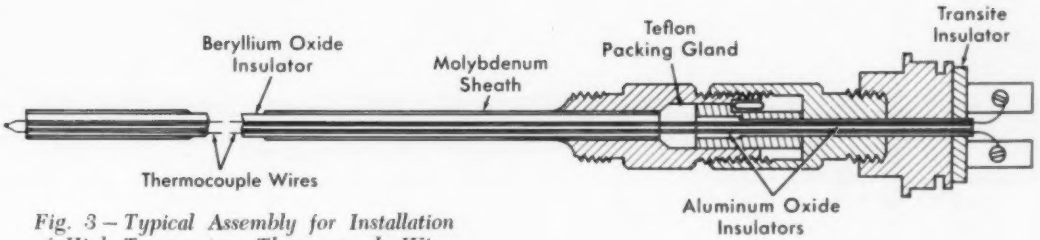


Fig. 3 – Typical Assembly for Installation of High Temperature Thermocouple Wire. Beryllium oxide is used as an insulator because it resists temperatures up to 4200° F.

Commercial Development

Upon completion of this preliminary research, at General Electric Co., Hoskins began further work aimed at the introduction of refractory metal thermocouples for commercial use. As of now, this program is concentrating on *(a)* making tungsten/tungsten-26% rhenium thermoelements readily available as matched pairs for various critical applications; *(b)* devising techniques for manufacturing both tungsten and tungsten-26% rhenium thermocouple wire with the consistancy required to meet a given calibration within prescribed limits of accuracy; and *(d)* attempting to find a suitable alloy combination for a compensating lead wire.

One of the primary requirements for success in this project was a high-temperature furnace. Accordingly, two specially designed units employing tungsten heating elements were constructed. These furnaces – shown in Fig. 2 – are capable of operating in the 4000 to 5000° F. range and can be used with vacuum, hydrogen, and inert-gas atmospheres. Operation at 4200° F. for periods exceeding 12 consecutive hr. is standard practice, and 700 hr. of performance at high temperatures have been achieved without maintenance.

These furnaces have also been used for sintering refractory metal powders. During this operation, the furnace temperature is controlled with tungsten/tungsten-rhenium thermocouples installed in the assembly illustrated by Fig. 3. Features of this design worthy of special interest are the molybdenum sheath and beryllium oxide insulator. Although the latter leaves much to be desired as a high-temperature dielectric, it is the only commercially available ceramic for thermocouple insulation that can resist higher temperatures than aluminum oxide.

Double-bore sleeves of beryllium oxide (sized to provide a loose wire fit and a relatively thick insulation layer) have been used successfully to 4200° F. At higher temperatures, however, the ceramic is not satisfactory because its electrical resistance decreases and vaporization becomes a problem. Incidentally, thin-walled molybdenum tubing in diameters down to 0.075 in. and beryllium oxide insulators to fit have recently become available; this should give instrument designers greater latitude.

The shortcomings of existing insulators highlight the most serious drawback in applying the full capabilities of tungsten/tungsten-rhenium thermocouples. Improved high-temperature insulators do not appear to be forthcoming, ncr does there seem to be a strong research effort in this field.

Production of Wire

Tungsten and tungsten-rhenium wire are being manufactured by powder metallurgy techniques in sizes down to 0.0005 in. diameter and in continuous lengths up to 2000 ft. Manufacturing facilities are being scaled up to handle larger powder compacts, a step that will minimize the problem of thermoelectric control.

At the present time, bare tungsten and tungsten-26% rhenium wires are being supplied as matched thermocouple pairs. Although each set is provided with its unique calibration, thermal emf. values observed to date have shown relatively small variations between wire lots. Accordingly, accumulated data have been used to formulate the tentative temperature-millivolt equivalents listed in Table I.

The low emf. of tungsten/tungsten-26% rhenium thermocouples necessitates special compensating lead wires. To answer this need, an alloy combination that will compensate for cold junction temperatures to 500° F. has been devised. As of now, alloys for lead wires are processed to match individual lots of thermocouple wire.

Work at Hoskins is now being concentrated on the production of tungsten and tungsten-26% rhenium wire that will continually reproduce a standard calibration. Exhaustive tests are in progress to provide a thorough understanding of variables affecting the reproducibility of thermal emf. When thermoelectric output can be controlled within reasonable tolerances, both tungsten and tungsten-26% rhenium elements will be supplied individually with a deviation

Table I – Temperature-Millivolt Equivalents for Tungsten/Tungsten-26% Rhenium Thermocouples*

	100° F.	200° F.	300° F.	400° F.	500° F.	600° F.	700° F.	800° F.	900° F.	1000° F.	
0° F.	0.080	0.263	0.571	1.025	1.560	2.194	2.916	3.702	4.547	5.466	
20	0.110	0.312	0.648	1.130	1.674	2.334	3.067	3.867	4.724	5.661	
40	0.143	0.366	0.732	1.236	1.794	2.476	3.222	4.034	4.904	5.858	
60	0.179	0.425	0.823	1.342	1.920	2.620	3.379	4.203	5.088	6.058	
80	0.219	0.500	0.921	1.450	2.054	2.767	3.539	4.374	5.275	6.260	
	1100	1200	1300	1400	1500	1600	1700	1800	1900	2000	
0	6.463	7.486	8.517	9.565	10.653	11.791	12.979	14.174	15.368	16.560	
20	6.665	7.692	8.725	9.778	10.876	12.025	13.217	14.413	15.685	16.795	
40	6.868	7.897	8.934	9.994	11.101	12.262	13.456	14.653	15.843	17.031	
60	7.073	8.103	9.144	10.212	11.328	12.500	13.696	14.891	16.082	17.266	
80	7.279	8.310	9.354	10.432	11.559	12.739	13.935	15.130	16.320	17.502	
	2100	2200	2300	2400	2500	2600	2700	2800	2900	3000	
0	17.739	18.936	20.115	21.280	22.410	23.542	24.686	25.843	26.979	28.112	
20	17.991	19.171	20.348	21.506	22.637	23.770	24.919	26.061	27.205	28.338	
40	18.228	19.407	20.580	21.731	22.863	23.997	25.152	26.291	27.430	28.563	
60	18.464	19.644	20.813	21.957	23.090	24.225	25.384	26.522	27.657	28.787	
80	18.701	19.880	21.047	22.184	23.315	24.455	25.615	26.751	27.885	29.011	
	3100	3200	3300	3400	3500	3600	3700	3800	3900	4000	4100
0	29.234	30.281	31.260	32.208	33.127	34.024	34.904	35.774	36.636	37.491	38.334
20	29.452	30.479	31.452	32.394	33.309	34.202	35.078	35.947	36.807	37.661	38.501
40	29.666	30.676	31.643	32.579	33.489	34.319	35.253	36.119	36.979	37.830	38.667
60	29.876	30.873	31.833	32.763	33.656	34.555	35.427	36.292	37.150	37.999	38.833
80	30.081	31.067	32.021	32.945	33.846	34.730	35.601	36.464	37.321	38.167	38.998
100											39.162

*Reference junction, 32° F.

from the standard specified for each wire lot.

Commercial availability of calibrated tungsten/tungsten-26% rhenium wire has prompted the use of this thermocouple in a wide range of applications. Representative examples are:

1. Stress-rupture and creep testing in reducing or inert environments.
2. Research on phase diagrams of high-melting alloy systems.
3. Determination of melt temperatures in vacuum induction furnaces.
4. Control of hydrogen atmosphere furnaces.
5. Determination of temperatures in nuclear reactors during pile experiments.
6. Short-duration measurements of jet engine exhaust temperatures.

Although these new thermocouples are intended primarily for ultrahigh temperatures, many of the present applications involve the range between 1500 to 3000° F. This stems from an ever-growing need for processing and testing materials in strongly reducing or inert environments that might affect the stability of standard thermocouples.

While the tungsten/tungsten-26% rhenium thermocouple represents a marked advance in high-temperature pyrometry, its present usefulness is limited by factors other than inherent thermoelectric properties. One of these previously mentioned – the lack of adequate insulation – imposes a 4200° F. temperature limitation. Other problem areas of major importance are the room-temperature brittleness of the pure tungsten wire and the questionable accuracy of optical pyrometers as a calibration standard at high temperatures.

Although much work remains to be done before the 5000° F. capability of these new thermocouples can be applied with full confidence, results to date have fully demonstrated the feasibility of refractory metal thermocouples for high-temperature use. Considering the vital importance of accurate measurement of ultrahigh temperatures and the intensified search for solutions to remaining problems, it seems certain that such thermocouples will become available as reliable, fully commercial products in the not too distant future.

The Items Shown Here Represent the Variety of Parts That a European Manufacturer (of the Borgward Automobile) Is Now Nitriding by a New Salt-Bath Process. Several manufacturers in this country are adopting the method

Progress in Nitriding

A New Nitriding Process From Germany

STAFF REPORT

Medium carbon and alloy steels can be nitrided in less than 2 hr. in a cyanate-containing salt bath to produce a case which is both file-hard and rough. Much intensive investigation has indicated that the method is suitable for applications where resistance to fatigue and wear are of concern. (J28k; CN, AY)

A NEW METHOD OF NITRIDING – developed by the Durferrit division of DEGUSSA* – has recently emigrated from Germany, and is beginning to make inroads in this country. Since coming here (in October 1959) it has attracted much attention, having already been the subject of much experimental work by American

*"DEGUSSA" stands for "Deutsche Gold und Silber Scheide-anstalt" which is translated as "German Gold and Silver Refiners". Despite the name, this company indulges in a number of different activities, one of which concerns this new nitriding method. The Kolene Corp., a Detroit company, is licensed to handle the process (which they call "Tufftriding") in this country.

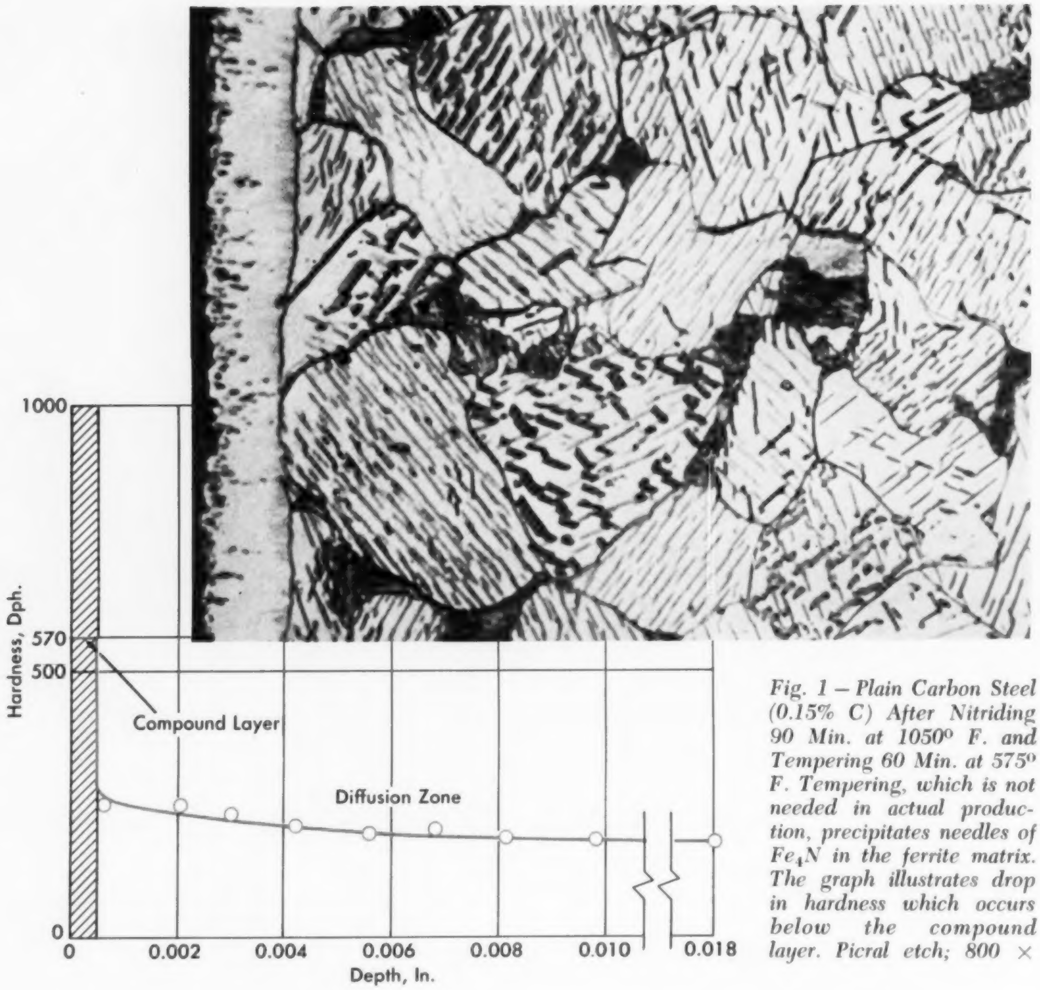


Fig. 1 – Plain Carbon Steel (0.15% C) After Nitriding 90 Min. at 1050° F. and Tempering 60 Min. at 575° F. Tempering, which is not needed in actual production, precipitates needles of Fe_4N in the ferrite matrix. The graph illustrates drop in hardness which occurs below the compound layer. Picral etch; 800 ×

manufacturers of automobiles, farm equipment, and other machinery. The process is now being used in production by several of these manufacturers.

How It Works

Unlike conventional long-time nitriding processes, this method, which employs a salt bath, can produce a tough, wear-resistant case in about 2 hr. In the salt bath, which contains a viscous solution consisting mostly of potassium cyanide and cyanate (KCN and KCNO), the cyanates (CNO radicals) break up into carbon, nitrogen and oxygen atoms. Since nitrogen dissolves ten times as much in ferrite as does carbon, many nitrogen atoms (and a few carbon atoms as well) enter the surface. Particles of Fe_3C quickly form at the surface, and act as nuclei for the iron nitrides, Fe_3N and Fe_4N. A thin, hard case soon appears. (According to x-ray diffraction tests, this case consists of Fe_3N and Fe_4N plus about 20% Fe_3C.) As treatment progresses, nitrogen diffuses below this layer and into the steel. In 1½ to 2 hr., as illustrated in Fig. 1, the case reaches a depth of about 0.018 in. Actual time of treatment depends on the grade of steel used and the results desired.

An important part of the process is the introduction of oxygen into the bath. Dry air is pumped in, the amount being determined by the dimensions and volume of the bath. The treatment can be adjusted to suit parts of different materials by regulating bath temperature (between 1000 and 1050° F.) and time of immersion (10 to 180 min.).

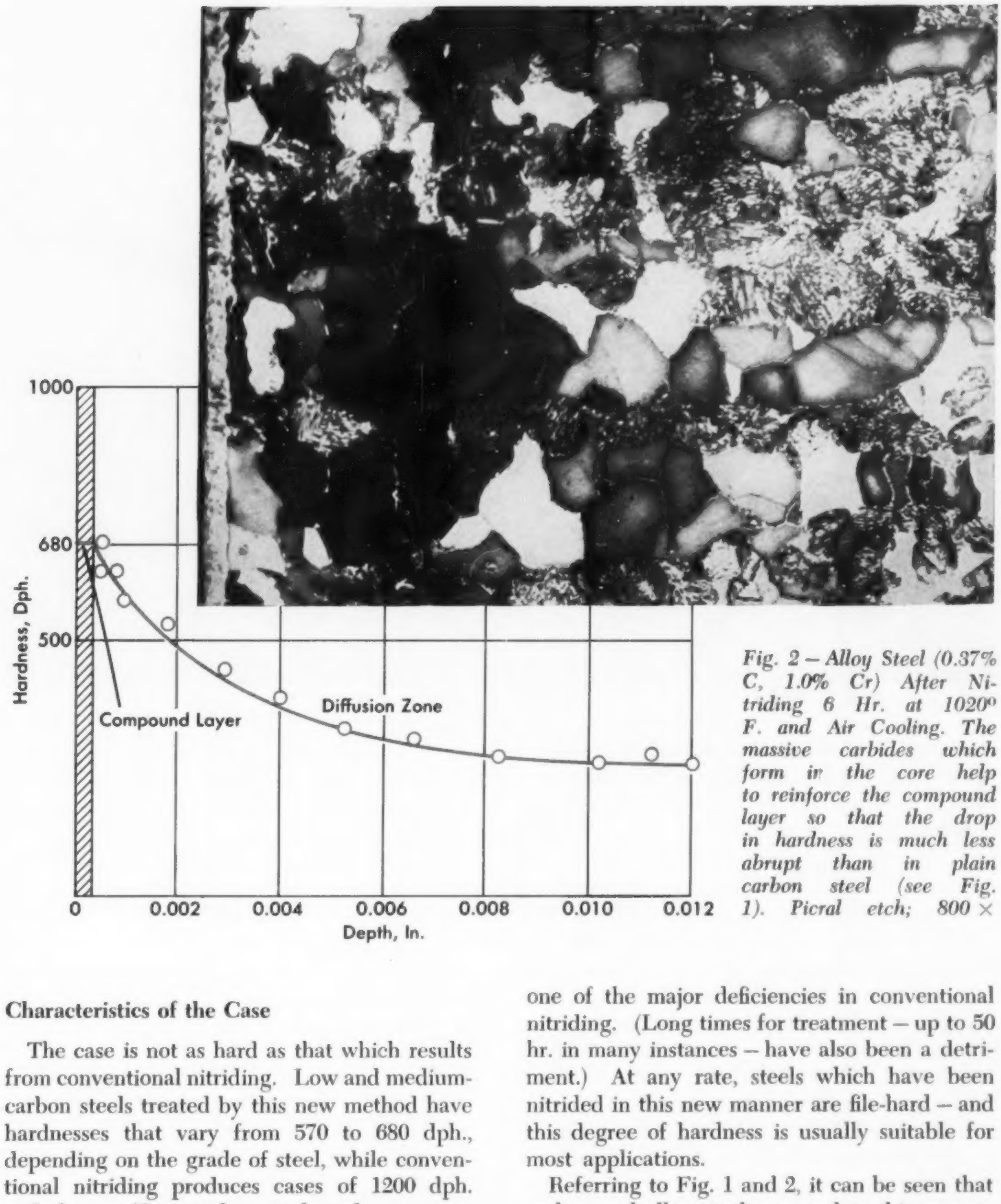


Fig. 2 – Alloy Steel (0.37% C, 1.0% Cr) After Nitriding 6 Hr. at 1020° F. and Air Cooling. The massive carbides which form in the core help to reinforce the compound layer so that the drop in hardness is much less abrupt than in plain carbon steel (see Fig. 1). Picral etch; 800 ×

Characteristics of the Case

The case is not as hard as that which results from conventional nitriding. Low and medium-carbon steels treated by this new method have hardnesses that vary from 570 to 680 dph., depending on the grade of steel, while conventional nitriding produces cases of 1200 dph. and above. (On stainless steels and even some air-hardening grades, the case developed by the new treatment will, however, be as high as 1000 to 1200 dph.)

Although the lower hardnesses that result on low and medium-carbon steels may sound like a drawback to this new nitriding process, it is well to remember that brittleness, which is unwanted, usually increases with hardness. This characteristic, in fact, has been one of the major deficiencies in conventional nitriding. (Long times for treatment – up to 50 hr. in many instances – have also been a detriment.) At any rate, steels which have been nitrided in this new manner are file-hard – and this degree of hardness is usually suitable for most applications.

Referring to Fig. 1 and 2, it can be seen that carbon and alloy steels respond to this process in different ways. Below the case on the 0.15% C steel, the hardness drops off markedly, though nitrogen has diffused inward (as the micrograph indicates). On the other hand, the greater depth of hardness inherent in the alloy steel (0.37% C, 1% Cr) is shown by the gradual drop in hardness below the case. Also, needles of Fe_4N appear in the carbon steel on tempering at 575° F. (nitrogen is in solid solution before

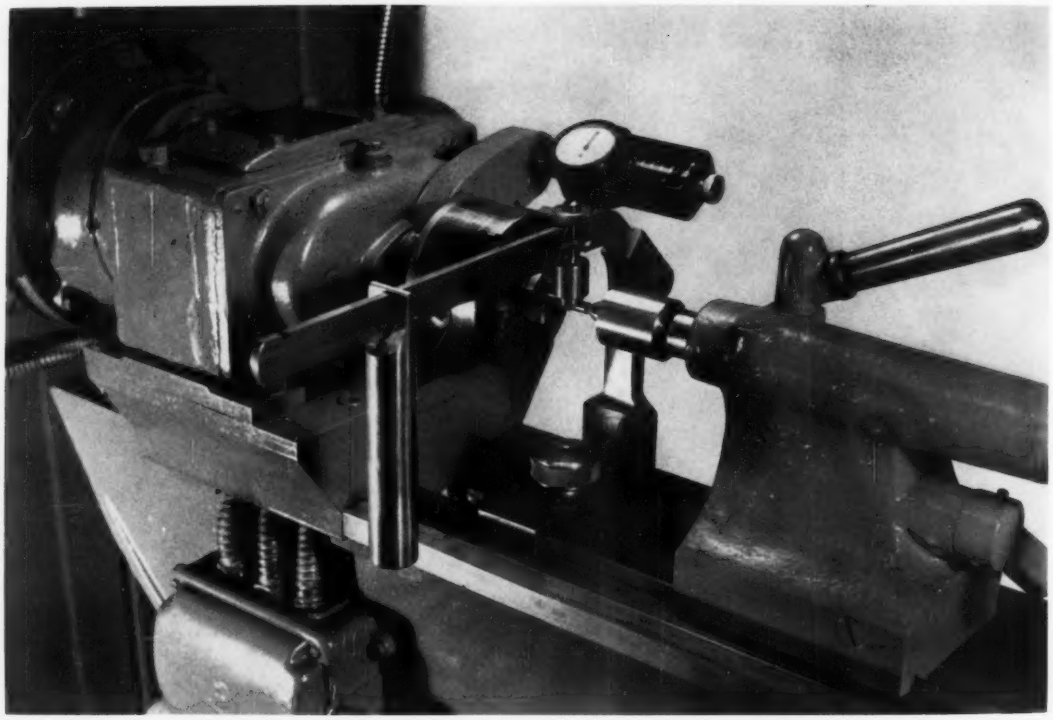


Fig. 3 — Faville-LeVally Wear-Testing Machine. As the test pin spins, pressure is exerted on it by the weight at the end of the lever arm. Wear is measured by the loss in weight

tempering), while massive chromium carbides are apparent in the alloy steel. In production, there is no necessity for this added tempering operation.

Cases Are Wear Resistant

According to tests on steel pins nitrided by this method, the cases are extremely resistant to wear. Shown in Fig. 3 is the Faville-LeVally wear-testing machine. When in operation, the test pin (unlubricated) spins, and pressure is exerted through a V-shaped channel. Figure 4 illustrates the results of this test of pins of 0.15% C steel which are in three different conditions. The untreated pin lost 15 mg. in about 2 min., the carburized pin (it was carburized at 1700° F. for 3 hr. and quenched in oil) lost 5 mg. in 4 hr., and the nitrided pin lost 1.5 mg. in 4 hr.

Another type of wear test employs a Faville-LeVally lubricant testing machine. In this, pressure is gradually increased on a spinning test pin by V-shaped jaws, and in time the pin can no longer withstand the frictional force. Figure 5 illustrates two pins of A.I.S.I. 3135 steel. One is untreated, the other nitrided in the salt bath. As is apparent, the untreated pin

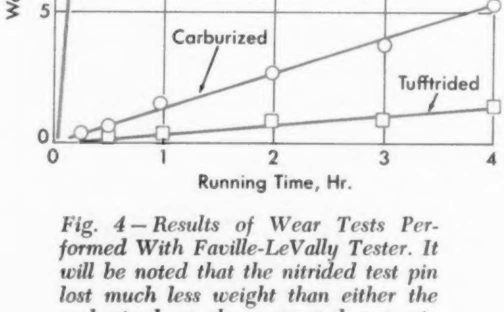


Fig. 4 — Results of Wear Tests Performed With Faville-LeVally Tester. It will be noted that the nitrided test pin lost much less weight than either the carburized or the untreated test pin

Fig. 5 – Two A.I.S.I. 3135 Test Pins, One of Which Was Nitrided in the Salt Bath While the Other Was Untreated. When they were tested in a Faville-LeVally lubrication testing machine, the untreated test pin wore rapidly, but the nitrided pin was virtually unaffected though it became so hot that it discolored from oxidation

wore rapidly and galled, while the nitrided pin wore very slightly. In fact, its wear resistance was such that it wore grooves in the jaws and became so hot that the surface discolored from oxidation.

Similar tests with treated and untreated malleable iron proved equally promising, as experimental work at the Chicago Malleable Castings Co. indicated. Engineers ran wear tests on treated iron blocks (1 in. square), and found that the new nitriding method improved wear resistance. After 75,000 cycles, the treated block had only worn at the rate of 0.190 g. per 10,000 cycles, while an untreated block (used as a control) had lost 0.871 g. According to the technical director of the Malleable Founders Society in Cleveland, Hans J. Heine, this treatment can increase the wear resistance of malleable iron parts up to ten times for specific applications.

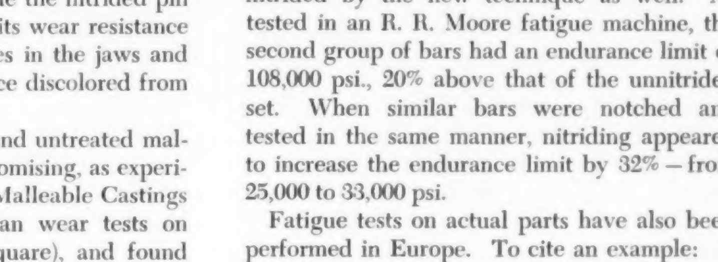
It must not be thought that the apparent increase in resistance to wear occurs in tests only; actual parts such as gears and cast iron cylinder liners are now being nitrided by the new method in regular production. According to the manufacturers of the Porsche and the Borgward, two German automobiles, the method has been very successful in reducing wear and increasing fatigue resistance in many components of the cars. (Some Borgward parts are shown in the photograph at the head of the article.)

Nitriding Aids Fatigue Properties

Another important feature of this process concerns resistance to fatigue. Tests of various types have been run here and in Germany, and all of them show that the fatigue life is significantly increased. For example, Fig. 6 illustrates the results obtained here during tests on two sets of bars of A.I.S.I. 4140 steel. Both groups were quenched and tempered (Rockwell C-30 to 32), but one set was subsequently nitrided by the new technique as well. As tested in an R. R. Moore fatigue machine, the second group of bars had an endurance limit of 108,000 psi., 20% above that of the unnitrided set. When similar bars were notched and tested in the same manner, nitriding appeared to increase the endurance limit by 32% – from 25,000 to 33,000 psi.

Fatigue tests on actual parts have also been performed in Europe. To cite an example: A series of crankshafts, made of a 1% Cr steel containing 0.37% C, was heat treated to 128,000 psi. After being surface hardened by three different methods – induction alone, induction plus shot-peening, and salt-bath nitriding – the crankshafts were tested by bending to find the fatigue limit. For the induction-hardened shaft, the limit was merely 14,900 psi.; shot-peening raised the limit to 16,400 psi. Nitriding by the new method, however, gave the crankshafts a fatigue limit of 27,000 psi., a value

Fig. 6 – Fatigue Tests on Treated and Untreated Bars of A.I.S.I. 4140 Indicate That Nitriding Increases Fatigue Life Considerably. Both sets of test bars were heat treated to Rockwell C-30 to 32 for these experiments



which represents an 80% increase over that of the induction-hardened shaft.

Similar results prevailed in other crankshafts that were forged of a steel containing 0.15% C, 1.5% Cr, and 1.5% Ni and then treated by two methods, induction hardening and nitriding. The nitrided shaft had a fatigue limit of 24,800 psi. while the limit of the induction-hardened crankshaft was 19,900 psi. It might be added that crankshafts made of gray cast iron and nodular iron were also benefited by salt-bath nitriding.

Limitations Are Few

Like all case-hardening methods, this technique of salt-bath nitriding is subject to some limitations. One of these obviously concerns heat treatment characteristics. Since nitriding is performed between 1050 and 1060° F., the tempering temperature is limited to that range or above, because heat treatment precedes nitriding. Otherwise, the part will be tempered further if it is nitrided at a temperature higher than that used during the original tempering treatment.

This characteristic, of course, acts to limit the grade of steel to the medium carbon and alloy grades. Because low-carbon steels are structurally soft when tempered at 1000° F. and over, they will not support the thin cases formed by nitriding. In fact, according to research performed by one manufacturer, the part to be nitrided must be completely stable (with regard to residual stresses) at 1110° F.

Another restriction is that the bath is apparently sensitive to copper in any form. This means that parts brazed with copper alloys cannot be nitrided, nor can copper stop-off plates be used to permit selective hardening. The latter limitation, a drawback common to all salt-bath hardening processes, prohibits spot hardening. However, this is not particularly important because the nitrided case is reasonably tough. Thus, the part can usually be nitrided all over without ill effects.

Many Applications in Industry

As mentioned before, many companies have been investigating this process. Several have found that it often answers the purpose when resistance to wear, abrasion, and fatigue are desired. For example, Burgess-Norton Mfg. Co. has determined that, in many instances, briquetting punches (made of high speed steel and used for compacting iron powder into forming dies) will last much longer when nitrided by this process. The exceptional increase in punch life – production rose from 7000 to 82,000 pieces on one set of tools – is apparently the result of better wear resistance and greater fatigue life.

Another company that has had good fortune with the new treatment is Euclid Div. of General Motors. Experiments have shown that it increases the wear resistance of punches to a great degree. These items, which are used in punching holes in steel plate, lasted six to seven times as long when nitrided by this method.

Still another company, Vickers, Inc., a division of Sperry-Rand, has installed, after considerable experimental work, a production unit in its Omaha (Neb.) plant to nitride pump shafts, valve spools, and other parts used in hydraulic equipment. According to engineers, the method is a convenient and reasonable way to increase the fatigue limit and provide a hard, wear-resistant surface. Another advantage of the process is that parts can be finish machined and hardened without detrimental changes in dimension.

The Demco Tool Co. also cites an example of success with this process. According to it, a well-known electronics firm in California makes a part of A.I.S.I. 1018 steel which requires broaching of several deep, close-tolerance, straight-sided slots on the surface. Because of the nature of these cuts and the softness of the material, the parts can only be cut satisfactorily when the broaches are extremely sharp. As soon as the broaches start to get dull, the chip which is being cut starts to expand, and extreme tearing and galling results. The greatest number of slots which could be machined between sharpenings was 1922, and the average number of slots was around half of this figure. However, when the broaches were nitrided by the new process after sharpening, it was possible to produce as many as 10,000 acceptable slots. Moreover, in no instance were fewer than 3000 slots machined.

The consensus is that this new nitriding process is a welcome addition to the ranks of surface-hardening methods. In the main, most companies that have experimented with it report good results with specific applications. As time goes on, and more knowledge is gained, many other uses should appear.

Gas Nitriding of Stainless Steel

*By V. J. COPPOLA**

Direct nitriding of stainless steel parts is practical; no special surface preparation is needed other than finish grinding, vapor honing, or lapping. (J28k; SS)

IN NITRIDING STAINLESS STEELS, inconsistent results are usually obtained unless some method is used to remove the surface oxide film which is believed to act as a barrier to nitrogen penetration. One widely used method is to sand or vapor blast the parts and then pickle them in acid. Although effective, this technique and others, whether electrolytic or chemical in nature, boost production costs appreciably.

At Cameron Iron Works, preparation of the surface by pickling and other means is no longer required. Finish-ground or lapped parts are nitrided directly in a retort which is sealed and purged of air before heating. In practice an absolute purge is neither practical nor necessary; however, to assure satisfactory nitriding, not more than 3% air (by volume) is permitted to remain in the retort before it is heated.

Effect of Oxides on Nitriding

The procedure which allows direct nitriding is based on tests with Type 410 stainless steel to determine the effect of various temper films (and a passive oxide film) on nitriding. Results shown in Table I and by the appearance of the tempered valve stems in Fig. 1 indicate that a passivating film and temper films produced at 900° F. or above do not affect the depth of the case. Sample 5 in the table is of particular interest because it underlines the importance of the purge cycle in this new nitriding technique. It was found that when the purge of the retort was inadequate (more than 3% by volume of air remained), an oxide formed when the parts were heated to the nitriding temperature. When this occurred, even surfaces that had been very carefully prepared failed to nitride.

It was also found that the length of time between final surface preparation and nitriding does not affect nitriding – an important production consideration.

Prior to development of this procedure, semi-finished parts were processed as follows: *(a)* sand-blast, *(b)* hot water rinse, *(c)* acid pickle at 150° F. for 1 min., *(d)* hot water rinse, *(e)* dry, *(f)* nitride, and *(g)* lap surface. Results were generally acceptable but quite inconsistent be-

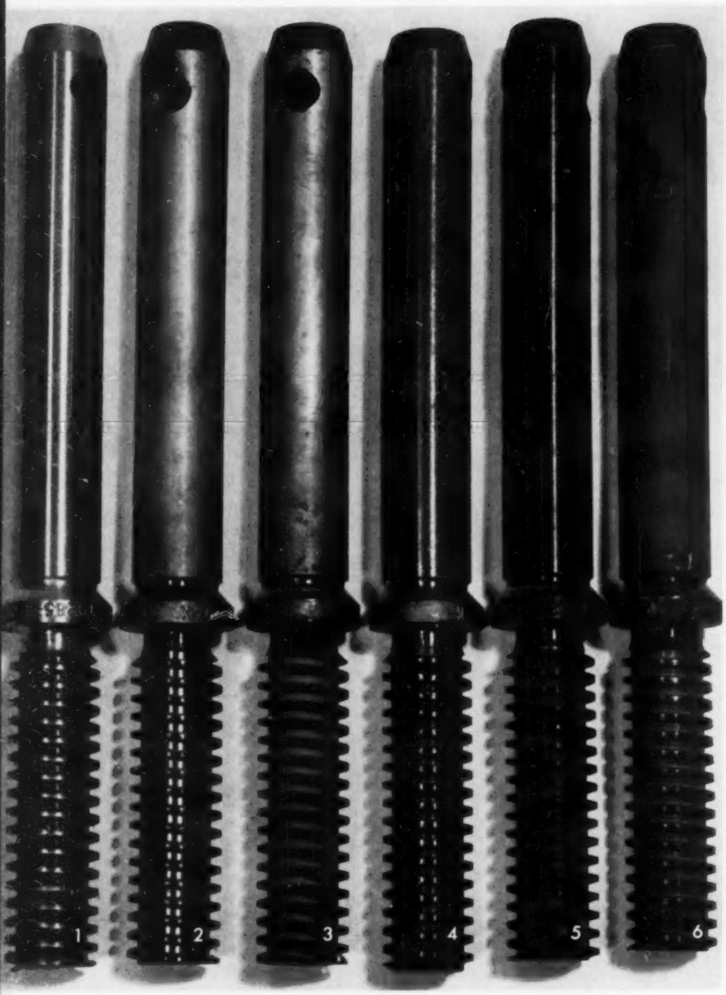
*Consultant, Houston, Tex. This process was developed while the author was assistant chief metallurgist of the Commercial Products Div. at Cameron Iron Works, Houston, Tex.

Table I – Effect of Surface Films on the Nitriding Reaction of Polished Type 410 Stainless Steel

Sample	Treatment Before Nitriding	Case Depth*
1†	Stored in alcohol, 3 hr.	0.008 in.
2	Naturally passivated in air at room temperature, 3 hr.	0.008
3	Naturally passivated in air at room temperature, 90 days	0.008
4	Artificially passivated in warm nitric acid, ½ hr.	0.008
5	Heated in air at 500° F., 1 hr.	(unmeasurable)
6	Heated in air at 700° F., 1 hr.	0.004 (spotty)
7	Heated in air at 900° F., 1 hr.	0.008

*Samples were nitrided at 975° F. for 48 hr. Retort was 98% purged with anhydrous ammonia before heating for nitriding.

†Control sample.



Treatment	Remarks
(1) As fabricated	Shank was finish ground; threads were coarse ground.
(2) Nitrided at 980° F. for 48 hr.	Disturbed surface metal prevents case from forming on ground threads, but smooth shank takes uniform case.
(3) Threads sand-blasted; nitrided as above	Sand blasting enables case to form on threads to same depth as shank.
(4) Tempered at 500° F.; nitrided	Oxide formed at this tempering temperature prevents case from forming.
(5) Tempered at 700° F.; nitrided	Same as sample No. 4.
(6) Tempered at 900° F.; nitrided	Uniform case on shank demonstrates that oxide formed at 900° F. (or above) does *not* inhibit nitriding. Case depth is variable in coarsely ground threads.

Fig. 1 — Effect of Surface Treatment and Tempering Temperature on Ability of Type 410 Stainless Valve Stems to Nitride Successfully. Surfaces with glossy appearance indicate poor nitriding results

cause of the many variables inherent in these operations. For example, sand-blasting often results in surface unevenness which causes problems in attempting to restore original flatness and parallelism after nitriding. Blasting irregularities also account for spotty nitriding. Surface streaking from acid or rinse water causes nonuniform nitriding. Many parts in each load then have to be prepared for re-nitriding. This disrupts schedules, is inefficient, and produces an appreciable amount of scrap.

The successful results obtained when nitriding lapped or smoothly ground (25 rms. or better) surfaces, without further surface preparation, have been attributed to the removal of a small but critical amount of disturbed or worked surface metal. It is virtually impossible to nitride stainless steel that has been machined by turning, milling or coarse grinding without special surface treatment, because of disturbed metal. These surfaces can be "activated" by a mild peening action such as sand or vapor blasting (see Fig. 1, sample 3). This beneficial effect on the nitriding reaction is not too clearly understood; it is only known that blasting induces compressive stresses in the surface which may counteract, to some extent, the tensile stresses developed during machining.

Book Review

Steel Castings... Uses, Properties and Design

Reviewed by W. K. BOCK*

STEEL CASTINGS HANDBOOK, Third Edition, edited by Charles W. Briggs, Steel Founders' Society of America, Cleveland. 670 p. $5.50.

LIKE THE TWO EDITIONS which preceded it, this handbook presents useful and necessary information to the designer, purchaser and would-be purchaser of steel castings and is not a reference work on foundry techniques. Its real purpose is reflected in the make-up of the book in which one chapter is devoted to manufacture of steel castings and 14 are given to discussion and data bearing on design and specification.

The first three chapters and perhaps the last contain material to whet the reader's interest in steel castings. The first presents the advantages of steel castings, the second shows numerous industrial uses of steel castings, and the third discusses purchasing in a manner which should go far to eliminate what remains of the old practice of "make it like the drawing". Purchaser and foundryman share one common objective: to produce economical parts which will stand up in service. Unless each knows the other's problems, this end cannot be obtained. The handbook sums it up by saying, "Modern casting problems have become more complex so that more information – not only of the foundry process, but also of the end use of the castings – is increasingly more important." Today's steel casting is a structural part capable of meeting the most exacting service requirements and the purchaser should make every effort to enable the foundry to produce it with a minimum of cut-and-try methods which increase cost and delay delivery.

Designers know that a liquid metal will flow into places and shapes where a solid metal can never be forced. This fact has been both a blessing and a curse to the foundry. It makes casting the most versatile, least restricted metal

*Director of Research, National Castings Co., Cleveland.

shaping process and one often used to execute designs which cannot be produced by other processes.

The old school of design recognized the flexibility of foundry techniques, but completely disregarded certain laws of science which govern the production of every casting. When the designer disregards fundamentals and the foundry agrees to "make it like the drawing", both share the blame when the castings turn out to be a collection of voids and nonmetallics surrounded by metal.

Most producers of metal shapes usually waste no time on improper designs, but in the foundry, the situation has been different. Putting metal in a given place is easier by casting than by the other process. What if defects occur? The foundryman has been quite ingenious in devising remedies. Unfortunately, the remedy is not always completely successful; it generally introduces other troubles and it costs money. Finally, designers and foundrymen have reached the conclusion that good castings can only be made from good casting designs.

No one has ever reduced the design practice for any metal shaping process to a concise set of rules. The usual procedure is to teach design by a set of examples of good and bad practices. In this, the Steel Castings Handbook follows current pedagogical practice and does it well.

If any criticism can be made of the handbook, one can point to its comment that "the ideal casting is one having only a single thickness". In modern interpretation this means that abrupt changes in section should be avoided, but the rule should say so and not be subject to interpretation. The advice to stick to uniform section size can be found in any discussion of casting design and, naturally, the designer is likely to consider it most important. If he ever produced a design with uniform sections, he would find the foundryman destroying the uniformity by putting lightening cores here and padding there to obtain the directional solidification which is a must for good castings. After that, what would the designer think of the other casting design rules?

Aside from this one rule, the recommended design practices that the Steel Castings Handbook sets down are the result of experience and studious application of the principles of physics, heat transfer, fluid mechanics, and other sciences. They emphasize that no one has ever made a good part from a bad design by any process and that a foundry must be given good designs if the inherent advantages of steel castings are to be realized.

In addition to a discussion of good and bad design practices, the handbook includes necessary data on tolerances, finish allowances, surface finish, minimum sections, and so on. One interesting section deals with cast-weld construction. Purchasers and foundrymen, each for reasons of their own, have frowned on welding. On the other hand, there are many complex designs which could be made better as two or more separate castings welded together before heat treatment. Since cast steel is almost always weldable, cast-weld construction is indicated in some places and the old prejudice should not stand in the way.

In dealing with characteristics of cast steels, the handbook not only lists the physical and mechanical properties, but discusses such matters as expected variations, effects of analysis and heat treatment and the effect of atomic radiation.

Proper specification of material is as important as proper design. To call for a "steel casting" is really no specification at all and to define certain minimum tensile properties may insure a certain quality of steel but ignores the importance of other properties.

In today's technology, service conditions are more severe and factors of safety are being lowered. Thus, we must turn to stress analysis by photoelasticity, brittle-lacquer techniques and strain gages to eliminate guesswork about stress distributions. One result of this increased sophistication is that the specification is being used not only to obtain quality steel in castings, but also to obtain the right steel in the best metallographic condition to stand up in service.

As a rule, the specification must not mention a property such as fatigue strength when it is obvious that no one will ever make acceptance tests to check compliance. But fatigue strength, notch factors, abrasion resistance, high-temperature strength, machinability, and corrosion resistance are often more important than the allowed properties. The relations between these important properties and the properties which can be specified are necessary for writing a realistic and useful specification. These data are not easy to present, but the editors of the handbook have done a fine job in treating the highly technical material thoroughly and in an easily read style.

The Platinum Metals Today

The design engineer, seeking unusual metals with desirable properties, may find that the metals in the platinum group have much to offer. Their resistance to corrosion by almost all acids and freedom from oxide film formation at high temperatures make them useful in many applications. (A-general, Q-general; EG-c, 17-57)

PLATINUM, A METAL FORMERLY ignored because of expense, has finally graduated from the chemical laboratory and is now a widely accepted industrial metal. Furthermore, the other members of the platinum family – palladium, iridium, rhodium, ruthenium and osmium – no longer invite a look of bewilderment or consternation. As a sign of this, world production of the platinum group, which after World War II totaled about 500,000 troy ounces per year, has steadily increased until today it runs over twice as much.

Why this increasing popularity? It is easily explained. Often, the properties of the platinum metals are superior to those of competitive materials, and at times, they are the *only* materials that can meet the stringencies of service. Surprisingly enough, circumstances can sometimes make them the most economical choice!

Of course, savings do not show up in initial materials cost – not with prices that range from a low of $24 per troy ounce for palladium to a high of $137 for rhodium. (An ounce of platinum itself costs $82.) This high initial cost, however, is frequently outweighed by ease of fabrication, by extended service life involving reduced downtime and maintenance, and by high recovery of the precious metals through refining.

A Variety of Fabrication Methods

Both platinum and palladium, the two most available and most generally applicable of the

This article is the joint effort of personnel in the Metallurgical Group, J. Bishop & Co., Malvern, Pa.

This Platinum Crucible Being Removed From a Melting Furnace Holds 12 Liters of Optical Glass

Table I – Properties of the Platinum Group Compared With Other Materials

PROPERTY	OS	RU	RH	IR	PT	PD	TYPE 302	AL	CU	NI
Specific gravity	22.5	12.2	12.4	22.5	21.45	12.0	7.94	2.70	8.96	8.90
Melting point, °F.	4900	4352	3571	4449	3224	2829	2680	1220	1981	2647
Electrical conductivity, I.A.C.S., %	17.5	20.1	35.6	31.6	15.8	15.5	2.29	63.1	100	—
Electrical resistivity ohms/cir. mil ft.	57.1	49.9	31.9	28.3	63.6	65.0	439.1	15.9	10.1	—
Thermal conductivity, Btu./sq.ft./in./hr.	—	—	348	609	493	493	113	1480	2728	638
Tensile strength room temperature, annealed, 1000 psi.	—	—	40★	97†	18	28	90	13	32	70
50% cold work	—	—	85	140	28 to 30	47	190	24	45	100
Elongation, % annealed	35	12	—	—	30 to 40	40	50	40	60	40
Modulus of elasticity, $\times 10^6$ psi.	80	60	75	42	21	17	28	10	16	30
Coefficient of linear thermal expansion,‡ $\times 10^{-6}$ in./in./°F.	3.17	—	4.50	3.56	4.79	6.41	10.00	12.34	8.87	6.95

★Pt-10% Rh. †Pt-20% Ir ‡70 to 100° F.

platinum group metals, can be easily handled by all usual metalworking operations. While iridium and rhodium are worked only with difficulty, and osmium and ruthenium are practically unworkable, they can be used as alloy additions to platinum and palladium.

Casting and hot forging (of platinum and palladium) are easily performed, as are the common cold working operations (strip and foil rolling, spinning, swaging, rod, tube and wire drawing, stamping and deep drawing). Sheet can be expanded, and wire can be woven into gauze. In fact, wire can be readily cold drawn with no intermediate anneals from a diameter of 0.250 in. down to 0.004 in. – this represents a reduction in area greater than 99.97%! With intermediate anneals, platinum wire can be further drawn down to 0.0003 in., and by the Wollaston (silver clad) process* it can be reduced still further to 0.00004 in.

Platinum can be welded (to itself and to base metals) by arc and gas welding; it is simple to hammer weld at about 2000° F. Platinum, palladium, rhodium and ruthenium are commonly electroplated, and plating with other members of the family is now under study. Metals of the platinum group can also be clad to base metals. As for malleability, platinum, palladium and certain of the alloys can be beaten into leaf which is less than 0.000005 in. thick. Most of the platinum metals can also be handled by the lost wax process, powder metallurgy, vapor deposition, and high-temperature liquid and gaseous spray.

Many Desirable Properties

The platinum metals are noted for their resistance to corrosives, resistance to formation of surface film, and stability at high temperatures. How these and other characteristics set the platinum family apart from better known metals is generally indicated in Table I.

The corrosion resistance of the platinum metals and their alloys is based upon their nobility. Platinum itself is virtually unaffected by all acids (except for slight attack by concentrated sulfuric acid at high temperatures or chlorine under oxidizing conditions). It also

*The "Wollaston" process is a method for producing fine wire in which the metal for wire is clad with another metal that is later removed by acid. The method allows production of wire which is much smaller in diameter than that of the dies through which the composite material is drawn.

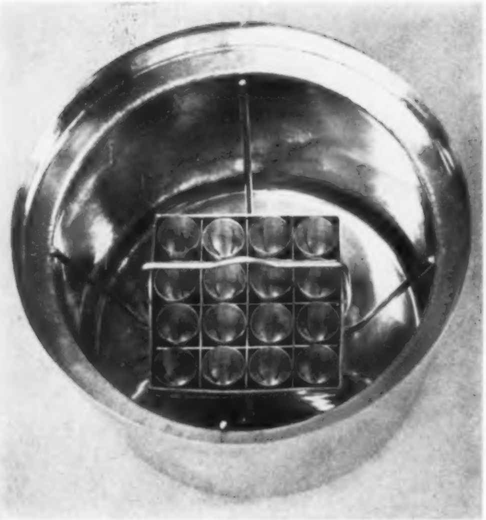


Fig. 1 – Corrosion Resistance and High-Temperature Permanence Make Platinum Useful for Laboratory Equipment Such as This Parting Apparatus Which Is Used in Assaying

resists most oxides, alkalis and salts, and is unaffected by liquid and solid organic materials. On the other hand, in reducing atmospheres it will form low-melting-point alloys or compounds with several other metals – lead, zinc and antimony are examples.

The other members of the platinum family are also noted for their nobility. Iridium, the most corrosion-resistant element known, cannot be dissolved by any acid including aqua regia. Rhodium, too, completely resists attack by every common acid (with the exception of hot fuming sulfuric acid). Palladium, though not as corrosion resistant as platinum, is widely used for selected applications because of its lower cost.

Platinum, however, offers the best combination of corrosion resistance and workability – and its already outstanding corrosion resistance can be further increased by alloying with iridium or rhodium. Workability is not hurt greatly, either. Generally speaking, the rhodium alloys, with their high resistance to volatilization, are used in high-temperature applications, while the iridium alloys, with their lower cost and greater strength, are preferred at lower temperatures.

Platinum in Industry

The platinum crucible has long been a standby in the laboratory. Because of the corrosion resistance and high-temperature permanence of the metal, such crucibles are regularly used in ignitions and fusions, particularly when the remaining ashes must be weighed in the same vessel. Figure 1 illustrates a parting apparatus used in assaying.

In larger, but less familiar, sizes the platinum or platinum-lined crucible plays an important part in the growing of large single crystals. It is not unusual for synthetic crystals (lithium fluoride and potassium bromide, for example) to be grown to a weight of more than 30 lb. or to a diameter of over 12 in. Platinum is used because it resists the molten salt and does not contaminate it.

Spinnerettes used in the rayon industry are usually made of 30% Pt, 70% Au or a 90% Pt, 10% Rh alloy. The spinnerette (or multiple die), which must stand up under the corrosive and erosive action of the cellulose and coagulating solution, may possess as many as 30,000 orifices, each of which can be as small as 0.002 in. in diameter. For increased erosion resistance of the platinum-gold alloy, its age-hardening characteristics can be used to advantage. The alloy can be fully fabricated while very workable, and later age hardened to an extremely hard and durable spinnerette.

Equipment for Molten Glass

In the melting and casting of high-quality glass, platinum's resistance to oxidation (and

Fig. 2 – Burst Disk Assemblies Including Platinum Disks and Stainless Steel Holders

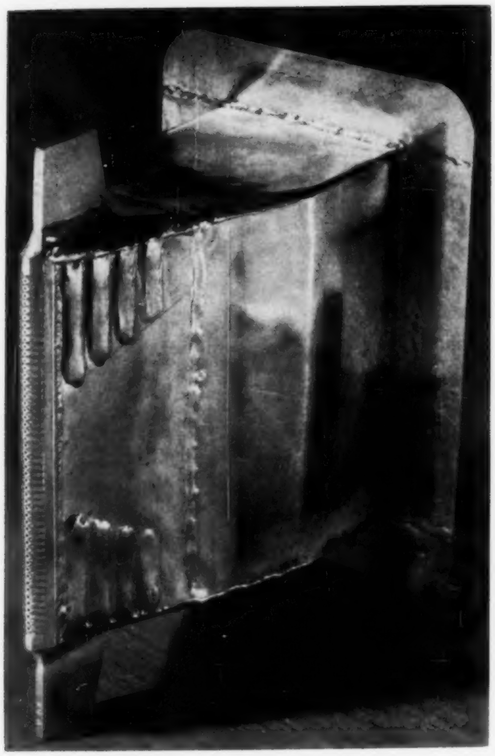


Fig. 3 — Erosion of Orifices Through Which Molten Glass Is Extruded to Produce Glass Fibers Is Minimized if Platinum or Platinum-Rhodium Alloy is used. The alloy has greater hot strength than pure platinum

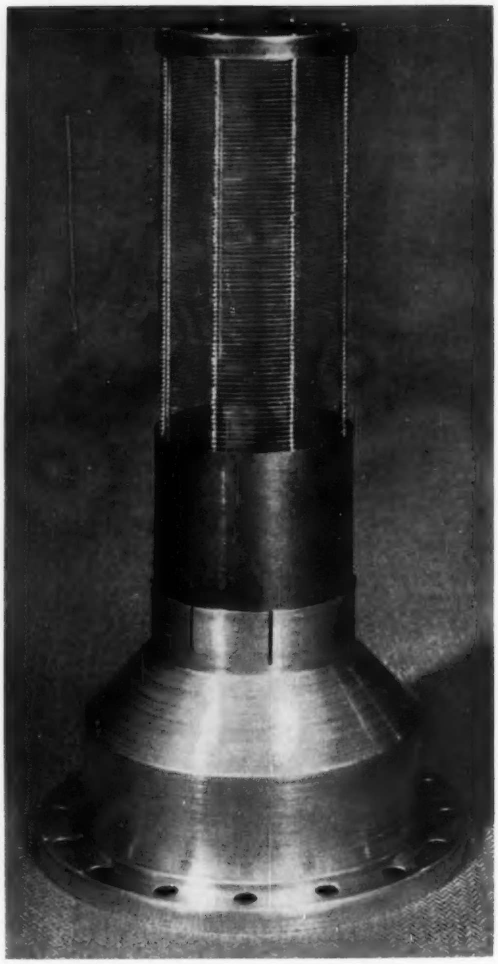


Fig. 4 — Control Grid Assembly for Large Vacuum Tube. The molybdenum wire (which has good high-temperature strength) is clad with platinum (which has negligibly low grid emission characteristics)

to attack by the molten glass itself) at high temperatures is very useful. Ordinary refractories used in such furnaces, although heat resistant, would be likely to dissolve in the glass. To prevent this, such refractories are sheathed with platinum. Furthermore, its melting point, 3212° F., is well above the service temperatures, 2400 to 2700° F. Where extreme purity and freedom from contamination are required, glass is not only melted in platinum pots, but is also stirred with platinum paddles and poured through platinum spouts.

Platinum is also used for orifices (Fig. 3) employed in extruding molten glass into such products as plate glass and glass fibers. Again, the precious metal resists erosion where refractories would break down under the rapid flow of glass at 2400° F. In the production of glass fibers erosion resistance is especially important because as many as 200 small orifices must maintain precision dimensions and alignment. Where these parts are subjected to stress and cannot be supported, a small amount (10%) of rhodium added to the platinum will greatly increase the hot strength. At 1830° F., for instance, where the tensile strength of platinum is about 4500 psi., the strength of the platinum-rhodium alloy is about 14,000 psi. Since it has a coefficient of expansion equal to that of many types of glass, platinum is also used in glass-to-metal seals, particularly where its additional properties of corrosion and high-temperature resistance are required.

Alloying Elements

As the metals engineer becomes more familiar with the platinum metals, he considers them more and more seriously as alloying elements, particularly for improving *(Continued on p. 116)*

Areas as Small as One Micron in Width Can Be Quantitatively Analyzed With the Microprobe Analyser Shown Here. This and other new research tools are expected to increase knowledge in the field of high speed steels very greatly within the next ten years

High Speed Steels Meet Tool Needs–II

*By PETER PAYSON**

To date, metallurgists have determined that high speed steels are hardened by tempering above 1000° F. because fine alloy carbides precipitate in the matrix. This phenomenon, called secondary hardening, makes it possible for tools of such steels to retain cutting edges at red heat. With newer research equipment in the offing, many more advances in tool steel metallurgy are expected in the next ten years. (Q-general, Q29, M27; TS-m)

In last month's article we discussed the many variations of the original grade of high speed steel (18-4-1) that are available today. During the course of experimental work needed in devising these many compositions, much has been learned about their metallurgical characteristics. In discussing these progressive advances we propose also to cover the metallurgical properties, structures, and heat treatments of high speed tool steels.

*Assistant Director of Research, Crucible Steel Co. of America, Pittsburgh. This is the second of two articles based on the 1960 Carnegie Lecture, presented by Mr. Payson before the Pittsburgh Chapter ⊕. Part I appeared in the June issue.

Why High Temperatures Are Needed

In the annealed condition, high speed tool steel consists of a mixture of alloy carbides in a

1600° F.,
1 Hr.

2100° F.,
15 Min.

2250° F.,
2 Min.

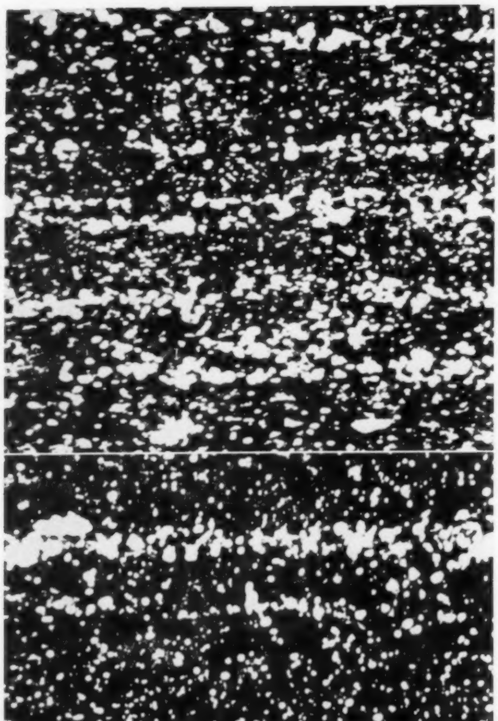


Fig. 1 – Residual Carbides in M2 High Speed Steel. This steel, as annealed, consists of chromium, tungsten and vanadium carbides in a ferrite matrix. More and more of these carbides dissolve in the austenite as the temperature rises. Thus, the austenite constantly gets richer in alloy content. These samples were quenched and double tempered. Nital etch; 1000 × (dark field)

ferrite matrix. When the steel is heated, these carbides gradually dissolve in the austenite, as Fig. 1 illustrates. This partly explains the reason for the use of high temperature to heat treat these high speed steels. Although austenite is present at 1600° F., only small amounts of the carbon and alloy in the steel will dissolve at that temperature. Thus, steel quenched from 1600° F. would have a relatively low hardness, under Rockwell C-60. Furthermore, it would develop no red hardness because the martensite formed on quenching has very little of the carbide-forming elements in it. As the austenitizing temperature is increased to 2100° F. and 2250° F., more and more carbides dissolve, thus introducing more alloying elements into the austenite. Then, the martensite that forms on quenching will be high in alloy content, and can develop red hardness.

The different carbides dissolve at different rates, the chromium-rich carbide, $M_{23}C_6$, dissolving completely in most steels, while the M_6C and MC types dissolve only partially. In fact, in the very high vanadium steels, M4 and T15, considerably more than 50% of the vanadium-rich MC type of carbide remains undissolved at the hardening temperature. These residual carbides are very hard, and contribute to wear resistance.

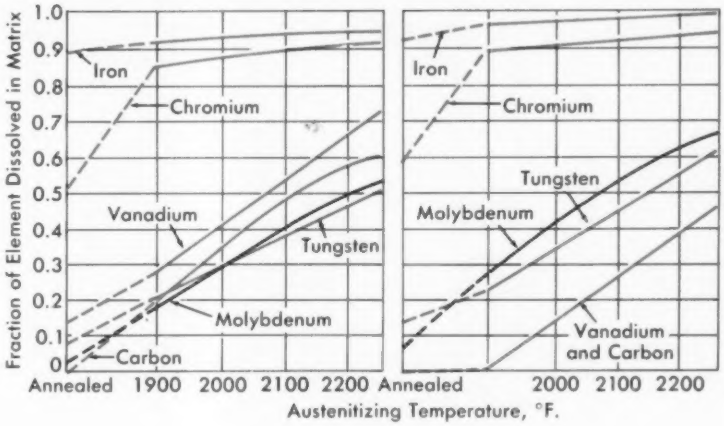
As stated before, the red hardness of high speed steel depends on the presence of carbide-forming elements in the austenite before it is quenched. Figure 2* shows how the austenite matrix becomes richer in alloying elements as the temperature increases. Practically all of the chromium in the steel dissolves at relatively low temperatures, but even at the maximum heating temperature only from about 50 to 70% of the carbon, vanadium, tungsten and molybdenum are dissolved. The rest of these elements are tied up in the residual carbides which are not just waste material. In the first place, they inhibit grain coarsening at the very high temperatures used in the heat treatment of these steels, and secondly, they provide some abrasion resistance to the steel to supplement that of the hard martensite.

Effect of Overheating

Now what happens if the steel is heated to higher than conventional temperatures? One

*"Carbides in High Speed Steel – Their Nature and Quantity", by F. Kayser and M. Cohen, *Metal Progress*, Vol. 61, June 1952, p. 79.

Fig. 2 – Partition of Elements Between Matrix and Carbides in High Speed Steels, M1 (Left) and M4. Most of the chromium carbides are dissolved at 1900° F.; vanadium, molybdenum and tungsten carbides dissolve much more slowly



answer is given in Fig. 3 which shows that M2 steel quenched from 2300° F. has a eutectic pattern at grain boundaries; this is evidence that a liquid phase was in the steel when it was quenched. The eutectic is found when the steel has been overheated appreciably and cooled rapidly from the high temperature. However, when the temperature is only somewhat above the conventional, massive carbides often form at the grain boundaries of cooled steel to show that incipient fusion has occurred. As Fig. 4 illustrates, such carbides also appear if the steel cools slowly from the high temperature (eutectic pattern will not be found).

Structures in Hardened Steel

In high speed steel that is quenched from the normal austenitizing temperature for hardening, the structure consists of residual carbides in a mixture of martensite and austenite. Although it is difficult to distinguish the retained austenite from the martensite in the as-quenched structure, tempering will darken the martensite. Then, the light-etching retained austenite may be easily recognized. The amount of austenite in the as-quenched steel can be measured by magnetic and x-ray diffraction methods, the latter technique being considered more dependable. In steel of this type, retained austenite normally ranges from about 15 to 25% depending on the composition and heat treatment of the steel.

Grain-boundary phenomena are of much interest. For one thing, high speed steel is the only martensitic steel that has grain boundaries in the normal as-hardened structure. However, if it is heated below about 2150° F., the boundaries do not etch. On the other hand, heating above 2150° F. does not change the width of the boundary, nor do changes in the rate of cooling from the normal austenitizing temperature affect the width to any degree. Grain boundaries always appear in normally hardened high speed steels – they cannot be inhibited, nor can they be altered much by retarded cooling.

It may be inferred that carbon concentrates in a slightly supersaturated solution at the grain boundaries during conventional heating for hardening, and that it precipitates in the form of the least soluble carbide (vanadium carbide) immediately after cooling starts. Up to this time, there has been no evidence that the slight amount of carbide precipitated at prior austenite grain boundaries has any practical significance in behavior of hardened steel.

Secondary or "Red" Hardness

In the normal as-hardened condition, high speed steel consists of martensite, austenite, and residual carbides with the alloying elements being split between the matrix and the residual carbides. It is reasonable to assume that the composition of the retained austenite is the same as that of the martensite, and that both constituents contain the carbon, chromium, vanadium, tungsten and molybdenum which were dissolved at the austenitizing temperature.

When the steel is tempered, hardness changes occur; these are shown schematically in Fig. 5*. Also shown are general trends for tempering curves of carbon steels and hardening curves of precipitation-hardening alloys. At the lower temperatures, the tempering curve of the high

*"Tool Steels", by J. P. Gill and others, American Society for Metals, Novelty, Ohio, 1944, p. 265.

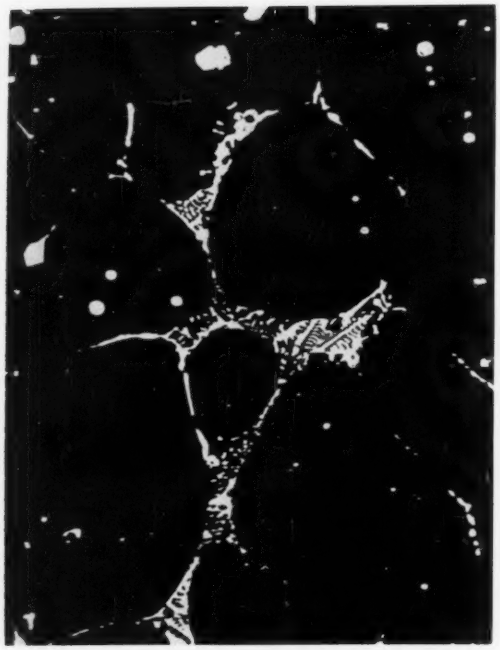


Fig. 3 – Eutectic in Grain Boundaries of M2 Heated at 2300° F.; This Is Evidence That a Liquid Phase Was Present. Eutectics such as this occur when the steel is overheated and cooled rapidly. Nital etch; 1000 × (dark field)

Fig. 4 – Massive Carbides Formed in M10 Tool Steel When Heated to 2275° F. and Cooled Slowly. Slow cooling allows carbon to diffuse from high-carbon liquid that appears in steel with overheating. Thus, massive carbides (instead of eutectics) are precipitated on cooling. Vilella's Reagent; 1000 × (dark field)

speed steel roughly parallels that of the carbon steel, while at the higher temperatures the same curve appears to match that of the precipitation-hardening alloy. The increase in hardness, which in high speed steels generally occurs between 700 and 1050° F., is referred to as "secondary hardening". When a high level of hardness persists over a long period of time at these relatively high temperatures, it is referred to as "red hardness".

Conventionally, high speed steels are tempered at about 1020 to 1050° F. to develop maximum secondary hardness. Although the pioneers in high speed steel development recognized that secondary hardening and red hardness were properties of the steels treated at these high temperatures, they did not consider the tempering operation to be an important part of the treatment. The mechanism of tempering was not clarified until 1939 when Cohen and Koh† showed that the austenite which is carried along with the martensite in the tempering operation is "conditioned" while it is heated at the tempering temperature, and subsequently transforms to martensite when the steel cools to room temperature. They also found that the presence of some 20% untempered martensite after the first tempering period made a second tempering desirable.

†"The Tempering of High Speed Steel", by M. Cohen and P. K. Koh, Ⓢ *Transactions*, Vol. 27, 1939, p. 1015.

The double temper treatment of high speed tool steels has now become almost universal. However, we still have much to learn about the conditioning mechanism which causes the retained austenite to transform while the steel is cooled from the first tempering heating.

How Red Hardness Develops

Red hardness is attributable to the precipitation and partial growth of alloy carbides during the tempering operation. For the steel to develop secondary hardening and red hardness, it is necessary for the carbide-forming elements, especially vanadium, tungsten and molybdenum, to be dissolved in the martensite. For those elements to be in the martensite, they must first be in the austenite. Yet, in the annealed steel, they are held in carbides which

do not dissolve until the steel is heated well over 1900° F. Quenching from the high temperature then locks the dissolved alloys in martensite. On tempering, Fe_3C is precipitated from the matrix at first. However, as tempering proceeds from about 800 to 1100° F., the iron carbide formed during the early stage of tempering goes into solution in the matrix. At the same time, however, an alloy carbide, MC, precipitates at 1000° F. and above. Though the composition of this carbide grows richer in alloy content with increase in temperature, the type remains the same since the MC type of carbide can dissolve appreciable amounts of tungsten, molybdenum and chromium. The hardness begins to drop off appreciably before the carbide composition stabilizes, red hardness being at a maximum while the carbide is becoming enriched in alloy content.

The expansion that accompanies the inception of alloy carbide precipitation (and which persists while the carbide is being enriched with alloy) has been generally overlooked in discussions of high speed steel, although data confirming this were shown in the previously cited paper by Cohen and Koh. Figure 6, which is taken from that article, shows increases in volume in 18-4-1 high speed steel that occurs with increase in tempering time at 1050° F. This expanded state lasts long after hardness begins to decrease indicating that after a tool has been multiple tempered at 1050° F. and finished to size it will not change dimensions in service when operated up to maximum capacity. On the other hand, it is conceivable that such a tool steel will "grow" if it is tempered below 1050° F. and is then put into service which will cause it to heat to that temperature.

Data on Red Hardness

Now that we have explained something about the mechanism of red hardness, it is appropriate to show some actual data. The steels tested for comparisons of red hardness are all commercial high speed steels of both the M and T types except one designated "Rex 49". Originally developed as a bearing material for high temperatures, Rex 49 was tried as a cutting material because it has excellent red hardness.

To evaluate red hardnesses, all steels were hardened conventionally and double tempered to maximum hardness. Samples of each were then reheated in salt baths for 5-hr. periods at 1100, 1150, and 1175° F. (It would be expected that steels that could withstand these reheatings without much loss in hardness would be able to withstand very severe cutting service.) Hardness results obtained after these reheatings – they are considered as indications of red hardness, incidentally – are shown in Table I. In this compilation, we first observe that vanadium at 2.0% and higher improves red hardness in the T steels; this may be seen by comparing T1, T2, and T9. Next, it appears that cobalt at 5.0 to 8.0% increases red hardness but slightly. The 12% Co steel, T6, seems better than the lower-cobalt steels but not any better than T9, the cobalt-free steel. (T9 has better red hardness than T15. At present it is difficult to explain this difference; it may be attributable to a better balance between carbon and vanadium in T9 or to more tungsten in T9 than in T15.)

What the Future Will Bring

In closing, I would like to discuss what the next ten years may bring in the field of high

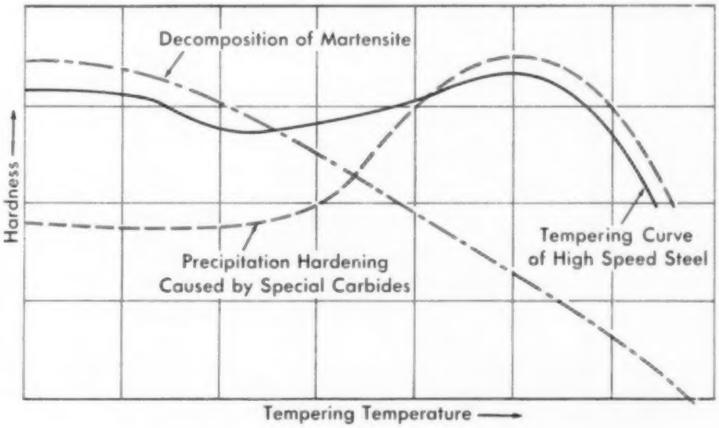


Fig 5 – Relationship Between Hardness of High Speed Steel and Tempering Temperature. At lower temperatures, the tool steel curve parallels the hardness curve for the decomposition of martensite, while at higher temperatures, it matches the curve for precipitation-hardening steels. This apparently indicates that secondary hardening is a precipitation-hardening phenomenon

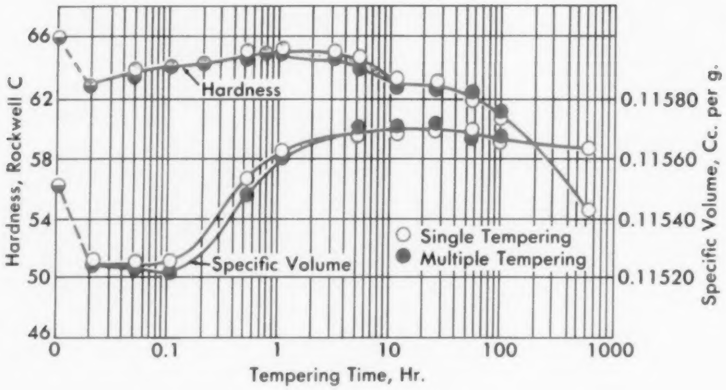


Fig. 6 – Changes in Hardness and Specific Volume of Hardened T1 (18-4-1) Tool Steel With Tempering at 1050° F.

speed steels. First, with the laboratory tools and techniques now available to us, particularly the electron microscope and microprobe analyzer, we should be able to get a good understanding of the mechanism which causes retained austenite in high speed steel to be "conditioned" during the 2-hr. heating at 1025 to 1050° F. Also, by studying the relatively small composition variations in carbon and the carbide-forming elements (chromium, vanadium, tungsten and molybdenum) along with determination of red hardness and cutting efficiency, we will learn how to balance the composition of high speed steel to obtain more efficient high speed cutting materials.

Since carbides, ceramics and diamonds become more limited in the machining of very hard materials, steels with very high hardnesses will probably be required for this purpose. The market for special-purpose steel should increase, particularly if a forgeable steel is produced of outstanding red hardness that can be heat treated to Rockwell C-70 or higher.

Although it is not likely that we can produce steels for general purpose cutting that will be lower in cost than the M-type steels, we should be able to improve their cutting efficiencies. If so, the long life cycle on the old standby, 18-4-1, will finally come to an end. This will be a true indication that we have made progress for the mark of progress is not so much the introduction of new materials but the elimination of materials on which we have been dependent in the past.

Table I – Comparative Red Hardnesses of Some Tool Steels

Grade	C	V	Co	Rockwell Hardness			
				Room Temperature★	1100° F.	1150° F.	1175° F.
M1	0.80%	1.0%	—	C-66	C-63	C-57.5	—
M2	0.80	2.0	—	65.5	62.5	58	C-56.5
M10	0.85	2.0	—	65.5	62	57	—
M3	1.0	2.7	—	66	62.5	56.5	—
M35	0.80	2.0	5.0%	66.5	63	57.5	—
Rex 49†	1.1	2.0	5.0	68	66	61.5	61
T1	0.70	1.0	—	66	62.5	57.5	—
T2	0.80	2.0	—	65.5	63	59.5	59
T9	1.20	4.0	—	66	64	61.5	60
T4	0.75	1.0	5.0	66	64	57.5	—
T8	0.75	2.0	5.0	66	63.5	60.5	59
T15	1.5	5.0	5.0	67	63.5	60	59
T5	0.80	2.0	8.0	65.5	63.0	60	59.5
T6	0.80	1.5	12.0	65.5	63.0	61.5	60

★As double tempered.
†Balance of composition: 4.0 Cr, 6.75 W, 3.75 Mo.

Machining Type 410 Stainless Steel, Quenched and Tempered to Rockwell C-45

Operation	Tool Material	Tool Geometry (a)	Tool Used for Tests	Depth of Cut	Width of Cut	Feed	Cutting Speed	Tool Life	Wear-Land (b)	Cutting Fluid
Turning	C-2 carbide	SR: 5°; SCEA:15°; BR: 0°; ECEA: 15°; Relief: 5°	½-in. square throwaway holder with mechanical chip breaker	0.100 in.	—	0.009 in./rev.	175 ft./min.	36 min.	0.016 in.	None
Turning	T-1 HSS (c)	SR: 15°; SCEA: 0°; BR: 0°; ECEA: 5°; Relief: 5°	⅝-in. square tool bit	0.060	—	0.009 in./rev.	45	54 min.	0.060	Soluble oil (20:1)
Face milling	C-2 carbide	AR: 0°; ECEA: 5°; RR: 0°; Cl: 10°; CA: 45°	5-in. diam., 5-tooth, inserted tooth face mill	0.100	2 in.	0.007 in./tooth	175	46 in./tooth	0.016	None
Face milling	T-15 HSS	AR: 0°; ECEA: 5°; RR: 0°; Cl: 8°; CA: 45°	4-in. diam., single-tooth face mill	0.060	2	0.005 in./tooth	70	50 in./tooth	0.060	Soluble oil (20:1)
Side milling Down milling setup	C-2 carbide	AR: 10°; ECEA: 5°; RR: −5°; Cl: 10°; CA: 45°	7-in. diam., 6-tooth inserted-tooth face mill	0.100	1¼	0.007 in./tooth	220	60 in./tooth	0.010	None
Slot milling Down milling setup	C-2 carbide	AR: −5° binegative; RR: −5°; ECEA: 1°; CA: 45° × 0.030 in.; Cl: 8°	6-in. diam., brazed 6-tooth slotting cutter	0.250	1	0.005 in./tooth	200	59 in./tooth	0.016	None
End milling	C-2 carbide	AR: 0°; ECEA: 3°; RR: 0°; Cl: 15°; CA: 45° × 0.030 in.	1¼-in. diam., 4-flute, heavy-duty, brazed-tip end mill (d)	0.250	1¼	0.001 in./tooth	90	100 in.	0.012	Soluble oil (20:1) (e)
End milling	T-15 HSS	35° RH Helix; CA: 45° × 0.060 in.; Per. Cl: 15°	¾-in. diam., 4-flute end mill (f)	0.250	¾	0.002 in./tooth	55	190 in.	0.008	Soluble oil (20:1)
Drilling	T-15 HSS	2-flute, 118° crankshaft point; 7° clearance	¼-in. diam. drill, 2½ in. long (g)	0.500 through hole	—	0.002 in./rev.	50	200 holes	0.016	Highly sulfurized oil
Tapping	M-10 HSS nitrided	4-flute taper tap; 60% thread	5/16-18 NC taper tap	0.500 through hole	—	—	20	100 holes	(h)	Highly chlorinated oil+inhibited trichloroethane (3:1)
Tapping	M-10 HSS nitrided	4-flute taper tap; 75% thread	5/16-18 NC taper tap	0.500 through hole	—	—	20 (i)	49 holes	tap breakage	Highly chlorinated oil+inhibited trichloroethane (3:1)

(a) AR = axial rake; RR = radial rake; CA = corner angle; SR = side rake; BR = back rake; SCEA = side-cutting edge angle; ECEA = end-cutting edge angle; Cl = clearance.
(b) Wear on the peripheral flank of the cutter.
(c) Use of T-15 HSS would permit slightly increased cutting speed.
(d) Cutter should be as rigid as possible.
(e) Applied as spray mist through axis of cutter.
(f) For end mills, ½-in. diam. and over. Flute length should be short as possible for maximum rigidity.
(g) Use stub length drills whenever possible.
(h) Test discontinued; tap still cutting.
(i) Improved tap life can be obtained at lower cutting speeds.

Source: Metcut Research Associates

Better Motor Cases for Missiles . . .

I—Improved Designs

*By JOHN CUNNINGHAM**

Solid-propellant motor cases can be made more reliable by such improvements as matching deflections of cylinder and end closures, using unsymmetrical bosses for reinforcing holes in domes, and employing spline joints for attaching nozzles. A method for applying uniaxial tensile data to biaxial design problems has also been helpful. (T24e, 17-51, Q27, Q25)

SOME TIME AGO, one of the most serious problems facing the missile industry was the premature failure of solid-propellant motor cases used in the Polaris, Minuteman and Zeus systems. Design requirements placed such heavy penalties of excess weight that all contractors were forced to build motor cases from high-strength steels (A.I.S.I. 4340, H11, Ladish D6A and the like), tempered to the 260,000 to 280,000-psi. ultimate strength range. Though tensile tests of these materials indicated adequate ductility, complete motor cases often failed in a brittle manner. In most instances, failure originated in a weld defect.

Since welds appeared to be the source of fabrication troubles, the answer seemed to be obvious – get rid of the welds. Before taking this step, however, engineers at Douglas felt that more should be known about the basic problems. Therefore, they began a systematic analysis including a careful evaluation of basic design philosophy, material selection techniques, process control and manufacturing methods.

As a result of these basic studies, we at Douglas have been able to produce efficient motor cases of conventionally welded sheet metal. Production-type cases are normally proof tested at 235,000 psi. hoop stress in the cylinder. When intentionally burst, they fail between 270,000 and 295,000 psi. The reduction of discontinuity stresses by proper design, has received major emphasis, and is further elaborated in this article.

Motor Cases Perform Multiple Roles

In designing motor cases, many factors must be considered. Modern solid-fuel motor cases, for example, serve in a dual capacity. Not

*Group Leader, Structures Section, Research and Development, Douglas Aircraft Co., Santa Monica, Calif.

only are they containers for propellants, they are also integral parts of the airframe. While fulfilling these twin roles, motor cases must operate in a combination of environments. During flight, they are subjected to internal pressures 15 to 100 times greater than atmospheric pressure, while, externally, they are exposed to both bending and compression loads. Finally, they must operate in two thermal environments: internal heat from the burning propellant – 4500 to 6500° F. – and external heat from aerodynamic friction which may be equally as severe. To meet these requirements, the designer must select the best materials, geometry, and structural concepts that can be justified by analysis, research and test.

Deflections Must Be Matched

A basic problem faced by the motor-case designer is the need for matching deflections throughout the structure. In other words, while the motor case is under stress, the deflections of each section must match those of the section adjacent to it. Since high-strength steels will not tolerate appreciable elongation, strain compatibility is essential.

The importance of matching deflections of adjacent sections is brought out when one considers the design of domes for rocket cases. The edges of most elliptical domes have a tendency to move inward when pressurized, but, at the same time, the cylinder tends to move outward. Since cylinder and dome must remain attached, the two opposing stresses produce local bending. These local bending stresses must be minimized or they can cause premature failure.

To solve this problem, the domes were designed according to known mathematical principals to produce a family of shapes whose edges move with the attached cylinder and skirt. Now, no extra forces are required to match up the displacements since the parts are designed to work together. In addition, the depth of the dome can be varied, more or less at will, to satisfy the geometrical requirements of the design. For example, the dome equation can be used to determine the shape that provides a maximum volume of propellant for a minimum dome weight, and at the same time minimize the stresses at the dome-skirt-cylinder joint. When the length of a motor case is fixed, it is extremely important to employ the optimum dome shape since significant increases in performance can be achieved by trading off extra propellant volume and structural weight.

To study the behavior of various types of case joints, our engineers devised and now employ a generalized analytical technique which involves dividing the structure into its elements. Then they determine equations of equilibrium, and compatibility of rotations and displacements for each element. These equations are solved to obtain the forces required to match the displacement. As a final step, the stresses at all points are calculated.

The maximum stresses in the dome and cylinder are shown in Fig. 1 as a function of dome thickness for a typical roll-seam weld joint. Note that, as the thickness of the dome edge is

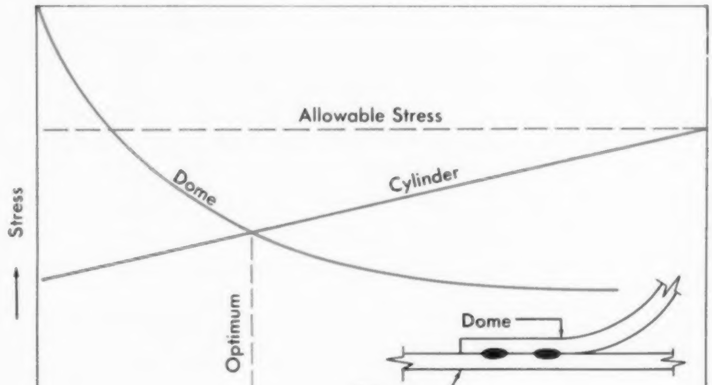


Fig. 1 – Effect of Dome Thickness on Bending Stresses Near Joint. Stresses in the dome decrease when it is thickened, but cylinder stresses get larger. There are optimum dome and cylinder wall thicknesses which will minimize the stresses. Inset illustrates type of joint

reduced, the dome stress increases. When the dome is made thicker, its stress decreases; however, the cylinder stress increases. Thus, there is an optimum dome thickness for which the local stresses in both the dome and cylinder are equivalent. (When the local meridian curvature of the dome is varied, it also affects the stresses in the dome and cylinder. Graphs are plotted to obtain the proper choice of meridian curvature.)

It is also important to know something about the distribution of local stresses near a typical joint. In general, the normal hoop and longitudinal stresses exist about 4 or 5 in. from a roll-seam joint in the cylinder. As the joint is approached, the hoop stress decreases because the unpressurized skirt prevents the cylinder from expanding. A given longitudinal strip of the cylinder will contain bending stresses which cause an increase in the longitudinal stress. It is the designer's job to minimize the longitudinal stresses by proper choice of dome curvature and local dome thickness.

Reinforcing Holes in Domes

The reinforcement of the holes in domes represents another type of problem which requires detailed study. It is easy to visualize that a reinforcement which is too rigid will act as a hard spot in the dome. On the other hand, if it is too flexible, it will cause a redistribution of stresses in the dome. When the twisting and stretching of the reinforcing ring are matched with the dome, the design equations become very involved and require a computer solution.

For some combinations of dimensions, an unsymmetrical boss leads to lower stresses in the

Fig. 3 – Photoelastic Model of Spline Joint, a Light Joint, Designed to Take Advantage of the Membrane Forces for Providing a Positive Metal-to-Metal Seal

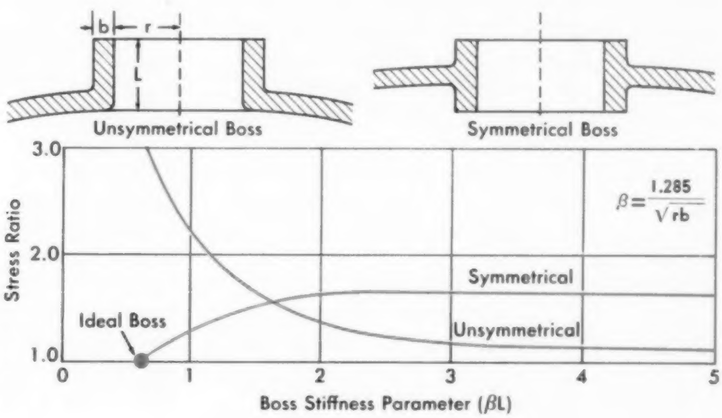


Fig. 2 – Bosses Used for Reinforcement of Holes in Motor Case Domes. For some cases an unsymmetrical boss develops lower dome stresses than a symmetrical boss

dome than does one that is symmetrical. (Figure 2 illustrates each type.) For a symmetrical boss, an ideal geometry – one which causes no stress concentration in the dome – does exist. Unfortunately, these "ideal" bosses are usually too small to allow proper installation of the igniter. A properly designed symmetrical boss may act like a hard spot and increase the stresses in the dome. By making it unsymmetrical, some flexibility can be restored, and the stress will be reduced.

Attaching Nozzles

The attachment of nozzles to thin, highly stressed domes is also a difficult problem. Designers need a "storable" joint in which the seal is not subjected to constant load, and, hence, cold flow. The answer, as Fig. 3 shows, is a spline joint designed so that the membrane forces in the dome and nozzle provide a positive seal on the nozzle-case faying surface when the motor is fired. The higher the internal pressure, the better the seal. It is important that the line of action of the forces pass through the centroid of the joint. Otherwise, the joint will rotate when loaded and cause discontinuity bending stresses in the dome. Incidentally, in studying this problem, our engineers use photoelastic models as an aid in determining values of the stress concentration factors for the various fillets and radii.

Converting Uniaxial Data to Biaxial Data

To predict the behavior of the high-strength steels in pressure vessels, it was necessary to develop a method for converting data from a uniaxial stress-strain curve to a biaxial curve. A theoretical method was evolved and verified by extensive experimental tests on small-scale and full-size motor cases. To illustrate, Fig. 4 shows the stress-strain curve for a tensile coupon along with curves for the same material when used in a sphere and cylindrical case. In the latter shapes, the yield point has been increased by a substantial amount, and, for a given strain, the stress is different. The agreement between theory and experiment is excellent, and all pressure vessels are now designed to the particular biaxial stress-strain curve appropriate for the design.

With this established method for converting uniaxial data to biaxial curves, our engineers can predict the strength at which a motor case will fail by "necking" or plastic instability. (This is the type of failure that would be expected if no serious flaws or stress concentrations existed in the motor case; it represents the absolute upper limit of performance.) Our studies show that the theoretical increase in strength predicted by the Hencky von Mises theory can only be achieved for materials with a flat-top stress-strain curve (one which levels off at the yield strength). For materials which exhibit strain hardening, the biaxial increase in strength will be less. As an example, for A.I.S.I. 4340 steel, a 12% increase in strength is predicted for the 2:1 biaxial stress field in a cylinder as compared to the strength of a uniaxial coupon. Since a large number of full-scale motor cases which have been intentionally burst-tested have achieved this strength, these results lead to but one conclusion: The maximum possible strength of currently available materials is being realized with rolled and welded cases. Significant weight reductions can still be achieved, however, either by reducing the "margin of safety" or by using new, superstrength materials.

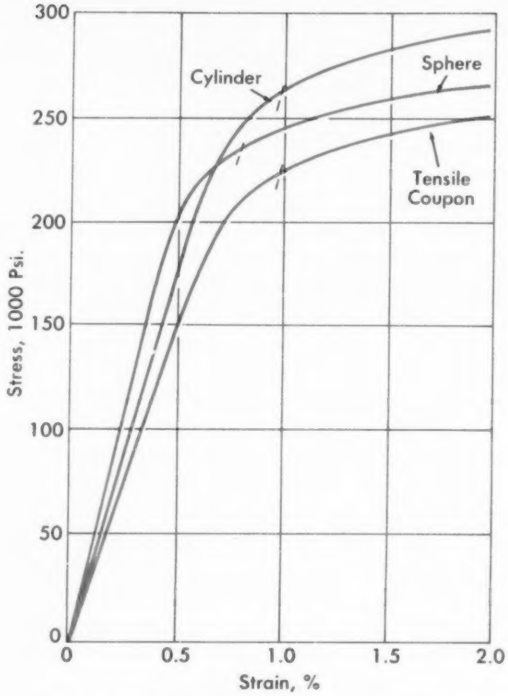


Fig. 4 – How Uniaxial Stress-Strain Curves Compare With Biaxial Stress-Strain Curves. The same material, A.I.S.I. 4340, was used for the tensile test coupon, the sphere and the cylinder. Note that the biaxial yield strengths are higher and the elastic moduli vary for each shape

Better Motor Cases for Missiles . . .
II—More Accurate Tests

*By GUY V. BENNETT**

Test results from a new partial-crack tensile specimen correlate with behavior of pressure vessels containing similar cracks. Further refinements are expected to produce quantitative data which can be used in designing reliable lightweight motor cases. (T24e, 17-57, Q27, 1-54, Q26)

A MOTOR CASE for a high-performance, solid-propellant missile must be made of a material with a high strength-to-weight ratio which will be reliable at very high stresses. For this, three "strengths" are of prime importance: a high yield strength, a high burst strength, and a high strength in the presence of a flaw.

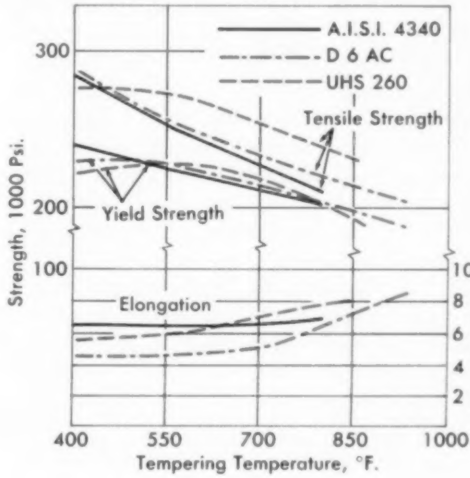
In the absence of a flaw or severe stress discontinuity, the first two, yield strength and burst strength, can be accurately predicted, as shown in the preceding article, from a standard uniaxial tension test. However, this is not yet true of the third "strength", which indicates the tolerance of a material for a crack or flaw. As the strength of an alloy is increased, the tolerance for flaws is generally decreased, and the problem of brittle fracture arises. Thus, if the alloy is to behave reliably in a rocket motor case, engineers must first have a thorough understanding of its fracture behavior in the presence of small cracks or flaws — cracks that are too small to be detected by the nondestructive testing techniques used today. For this, special tests are needed.

Early Test Methods Explored

Over the years, our engineers have experimented with many of the test methods devised for evaluating materials for rocket motor cases — tear tests, edge-notch and center-notch tension test, bend tests, and several others†. One test, used sometime ago by us, consisted of burst testing 10-in. diameter spheres. Made by welding two hemispheres together, these spheres were heat treated to the desired strength level and subsequently pressurized to failure. This test seemed rather appropriate because the material was being tested in a biaxial stress field in the presence of a weldment.

A large number of steels and other alloys were evaluated by this method. Some of the spheres exhibited burst strengths near the uniaxial tensile strength, while others burst at stresses well below the tensile strength. The low burst strength was generally associated with the presence of a prior crack which had not been detected by nondestructive testing before pressure testing. This correlation led to studies of the strength of these materials in the presence of a crack. The crack-tolerance stud-

Fig. 1 — Mechanical Properties of Three Typical Steels Over a Range of Tempering Temperatures. As far as yield strength, tensile strength, and elongation are concerned, these three steels are very similar. Compare with Fig. 2



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*Head, Metallurgical Research, Douglas Aircraft Co., Santa Monica, Calif.

†For a compilation and description of the various fracture toughness tests which have been used see the data sheet "Tests for Determining Fracture Toughness of Sheet Alloys", *Metal Progress*, August 1960, p. 100-B.

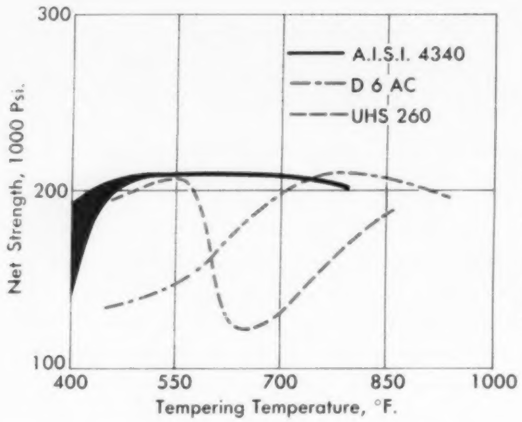


Fig. 2 – Net Strengths (in the Presence of a 2t Crack) of Steels Shown in Fig. 1 (Net Strength = Breaking Load ÷ Net Area). It will be noted that the net strengths vary widely with tempering temperatures indicating that the strength in the presence of a crack does not necessarily correlate with other mechanical properties (refer to Fig. 1). Also, tempering at high temperatures does not always raise the "crack strength"

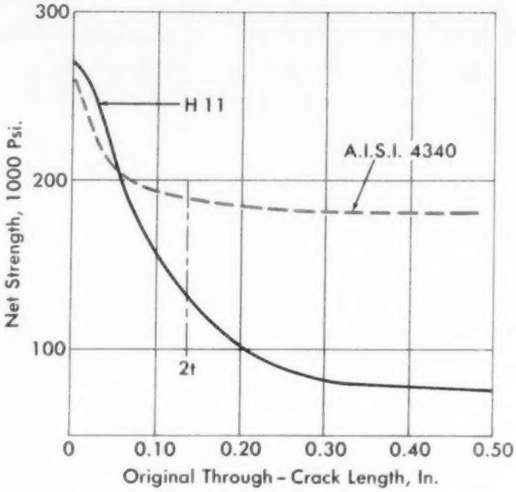


Fig. 3 – Effect of Through-Crack Length on Net Strengths of Two Steels. Though strengths generally decrease as crack lengths increase, the two steels are decidedly different from a quantitative standpoint

ies began with special tensile specimens (developed jointly with Battelle Memorial Institute). The specimens were sheet strips, 1½ in. wide, which contained cracks in the center that were 2t (t = thickness) long. To make the cracks, a small hole was drilled on the centerline. Then, the specimen was cycled in an axial-load fatigue machine until a through-crack formed and subsequently propagated to a length equal to twice the thickness of the specimen. The specimens were then heat treated to the desired strength level and tested in tension to failure.

With this type of specimen, numerous alloys were evaluated. To demonstrate some interesting observations, the results obtained on three steels have been selected. Their mechanical properties, plotted as a function of tempering temperature, are shown in Fig. 1. Note that the tensile strengths, yield strengths, and elongations of the three steels are approximately the same for any one tempering temperature.

However, as Fig. 2 shows, the strengths of these steels vary in the presence of a 2t through-crack. In the graph the "net strength" (breaking load divided by the net area*) is plotted against tempering temperature. As can be seen, A.I.S.I. 4340 has a net strength independent of tempering temperature (for the range shown) except that considerable scatter is evident in results on specimens tempered near 400° F. On the other hand, D6AC displays an increasing net strength with increasing tempering temperature, with a maximum occurring at 800° F. Still different is UHS 260; its net strength is at a minimum with a 650° F. temper.

*"Net area" equals the cross-sectional area of the specimen minus the area of the crack.

It is obvious, therefore, that the strength in the presence of a crack cannot be judged by the yield and tensile strengths. Incidentally, the data also seem to negate the generalization that increased crack tolerance can be obtained by lowering the yield strength (increasing the tempering temperature).

Effect of Varying Crack Lengths

The picture is further complicated if the length of the crack is varied. In Fig. 3, the net strength is plotted as a function of the length of the crack for A.I.S.I. 4340 and H11, both of which possess the same tensile strength. Though the net strength decreases as the crack length increases in both steels, the values are quite different quantitatively. Therefore, if the "2t" criterion is used for selecting the alloy with maximum crack tolerance, A.I.S.I. 4340 would be chosen. Note, however, that the two curves intersect at a crack length of about 0.060 in., and that the net strengths of the two steels are almost the same for crack lengths 0.060 in. and smaller. Consequently, if the problem concerns the presence of undetected cracks

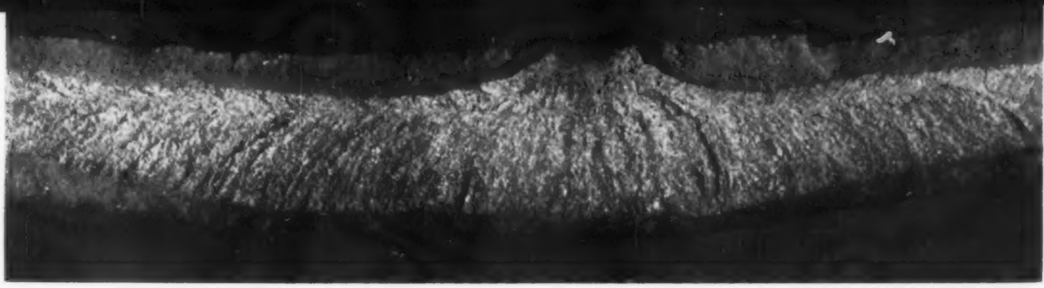


Fig. 4 — Prior Crack in a Pressure Vessel Fracture Surface. The existence of the sheer lip on the face directly opposite the prior crack indicates that the crack did not propagate completely through the section before onset of rapid fracture. Material: A.I.S.I. 4340; wall thickness: 0.140 in.

shorter than 0.060 in., both steels would possess the same strength and presumably would exhibit the same degree of reliability.

Effect of Partial Cracks on Strength

Up to this point, only the effect of cracks extending through the thickness had been studied. Such cracks, however, had never been observed during tests on spheres. Rather, all the cracks previously observed extended only partially through the section, as shown in Fig. 4. The presence of a shear lip along the face directly opposite the partial crack indicates that the crack did not propagate completely through the section before onset of rapid fracture. Therefore, the effect of through-cracks on strength cannot be quantitatively applied to the problem of partial cracks, since the energy required to propagate the two types of cracks is quite different.

Realizing this, engineers at Douglas began to develop a test method for studying the effect of partial cracks on the strength of materials. The specimen which they devised contains a surface crack (in the center) introduced by fatigue. (It is quite similar to that employed for through-cracks except that no hole is drilled along the centerline to start the fatigue crack.) With this technique, cracks can be introduced in material which is in either the annealed or hardened condition, and no environmental effects (such as those occasioned by low temperature or hydrogen embrittlement) are incorporated. Although refinements of the technique are required before a thorough study of the effect of cracks partially through the thickness can be undertaken, considerable data has been obtained to date. For example, Fig. 5 shows the effect of original crack length (through and partial) on net strength of H11 steel specimens heat treated to the same strength level (270,000 psi. tensile strength). As might be expected, partial cracks which are as long as through-cracks do not lower the strength as much.

Another interesting observation is shown in Fig. 6 and 7. Fracture surfaces at the bottom and center of Fig. 6 are two specimens of A.I.S.I. 4340; the specimen pictured at the top

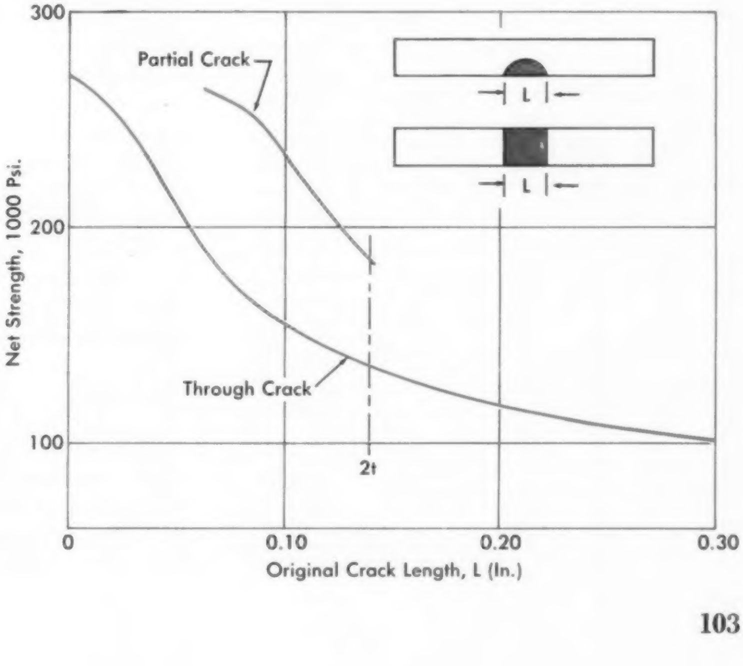


*Fig. 5 — Comparison of Effect of **Through-Cracks** and Partial Cracks on Strength of H11. A partial crack of the same surface length as a through-crack does not lower the strength as much as the through-crack*

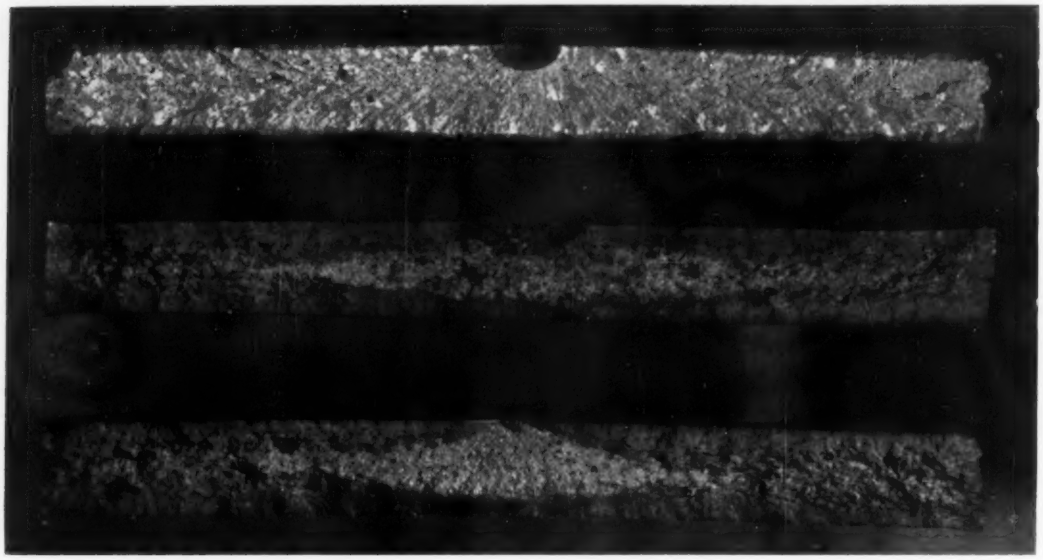


Fig. 6 – Fracture Surfaces of Partial-Crack Tensile Specimens of Two Steels. The specimen at the top (H 11 steel) displays a brittle fracture. Wider shear lip on the other fracture surfaces (A.I.S.I. 4340 steel) indicate ductile fractures

is made of H11. In each specimen, the prior crack is discolored by oxidation resulting from heat treatment after cracking. Note that the cracks in the center and bottom specimens did not propagate completely through the section before onset of rapid fracture – the shear lip on the face opposite the crack attests to this fact. Also, both of these specimens exhibit a considerable shear lip on the fracture face. On the other hand, the H11 specimen reveals very little shear on the fracture face, and has the appearance of being very brittle.

Yet, the net strengths of these two steels in the presence of partial cracks, which are plotted in Fig. 7 as a function of partial-crack length, are very similar. The data for both steels fall into the same band of scatter, and both steels possess the same strength in the presence of cracks which are the same size. Such data suggest that the amount of shear on the fracture surface may not be indicative of fracture toughness, at least when one is concerned with cracks extending only partially through the thickness.

Finally, a limited amount of data have been obtained for correlating uniaxially stressed partial-crack specimens with the behavior of

Fig. 7 – Net Strengths of Partial-Crack Specimens Whose Fracture Surfaces are Shown in Fig. 6. Though one steel appears to be brittle and the other ductile (according to the appearance of the fracture surface), their net strengths are comparable when partial crack lengths are equivalent

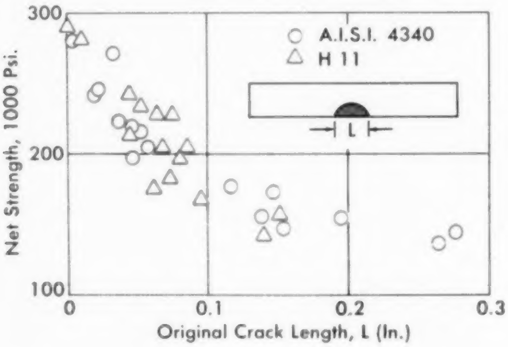
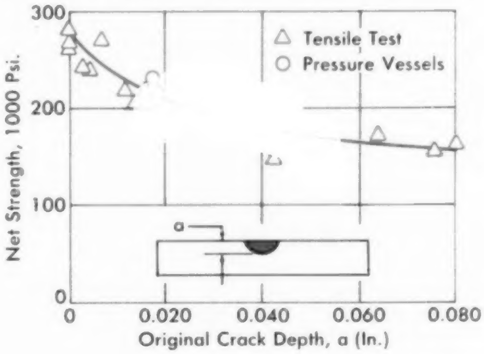


Fig. 8 – Comparison of Results of Tests on Tensile Specimens and Pressure Vessels of A.I.S.I. 4340. Note the excellent correlation in results



pressure vessels containing partial cracks. The data plotted in Fig. 8 were obtained from tests on pressure vessels (10-in. diameter spheres) and partial-crack tensile specimens which were fabricated from A.I.S.I. 4340 and heat treated to the same strength range. For the pressure vessels, the net strength is calculated by the following formula:

$$\text{Net Strength} = \frac{\text{Pressure} \times \text{Radius of Sphere}}{2 \times \text{Thickness Remaining at Crack}}$$

Admittedly, the data for pressure vessels containing prior cracks is quite limited. However, they suggest excellent correlation of the partial-crack tensile test with pressure vessel behavior. If further testing verifies the excellent correlation obtained to date, the partial-crack tensile test can be used to obtain quantitative data for use in the design of rocket motor cases in addition to the evaluation of materials and processing variables.

Better Motor Cases for Missiles . . .
III–Advanced Fabrication Methods

*By R. E. HEISE**

Rigid specifications on incoming material and meticulous quality control throughout production enable Douglas Aircraft to turn out solid-propellant motor cases which consistently meet proof stresses of 235,000 psi. They are made of A.I.S.I. 4340 sheet by the conventional roll-and-weld process. (T24e, Q26, K-general, J-general; AY)

WITH THE AID OF ADVANCED DESIGN and material testing concepts, along with meticulous quality control, Douglas now produces dependable motor cases which, as Fig. 1 shows, consistently meet proof tests of 235,000 psi. hoop stress. Furthermore, this high strength and high degree of reliability have been achieved with standard fabrication methods (the roll-and-weld technique) and a conventional alloy, A.I.S.I. 4340 heat treated to the 260,000 to 280,000-psi. strength range. In the roll-and-weld method, the cylindrical portion of the motor case is made from formed sheets which are fusion welded longitudinally. Closures at each end are formed sheet and forgings which are resistance seam welded into the cylinder such that portions of the cylinder are used as integral skirts.

Quality Control Is Essential

In the production of motor cases for two major weapons systems, the Nike Zeus and the Skybolt, we have learned that processes and their control determine the quality of the product. To improve the reliability of our hardware, we have had to insist on improvements in material, improvements in fabrication equipment and improvements in processes and process control.

Although the first material received for fabrication into motor cases was the best wide, thin sheet then available commercially, it often had some undesirable characteristics. For example, the sheets had measurable surface decarburization, were not as flat as necessary to assure the proper fit for welding operations, and mechanical properties did not always come up to the expected level required for high-strength motor cases.

The improved process control for the material had to begin at the steel mill, and this was achieved as soon as we knew what we required. We then conveyed the information by means of special and stringent specifications. To be sure our requirements were met, we instituted special control measures to determine whether we were really getting our money's worth. An ultrasonic method for measuring sheet thick-

*Metals Research Coordinator, Douglas Aircraft Co., Santa Monica, Calif.

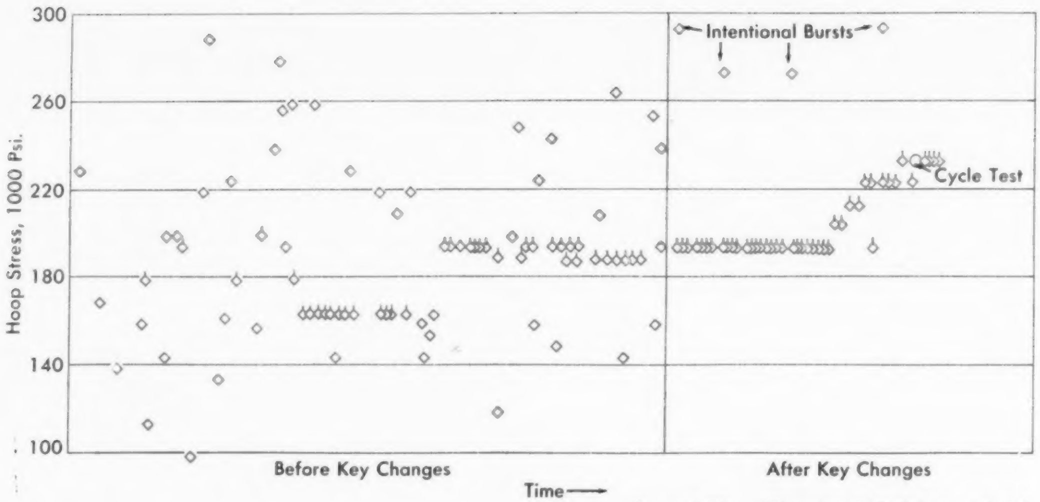


Fig. 1 – Control Chart Showing Reliability of Solid-Propellant Motor Cases. The "key changes" included improved control of decarburization, a change of pressure-test media from inhibited water to oil and a change in tempering temperature

ness on a 6-in. grid pattern was employed to inspect each incoming sheet to determine minimum gage as well as the tolerance range.

Today we specify thickness tolerance (for typical gage from 0.078 to 0.141 in.) of ± 0.005 in. Flatness, for 0.101 to 0.165 in. gage is not to vary more than 3% maximum based on the percentage of the distance between contact points of a straight edge when material is laid out on a flat surface. Material is to be free of complete decarburization (free ferrite), and the increase in hardness from surface to center shall not exceed two points Rockwell A. We also check the response to heat treatment of every sheet of every heat of steel on all incoming material to insure that substrength sheet will not be built into hardware. Improved mill practice has also reduced the decarburization and greatly improved the flatness of the sheets.

Welding Is Improved

In welding processes, improvements must begin at home. The first longitudinal fusion welds on motor cases were made by hand, a practice which introduced quite a few variables dependent solely on the man doing the welding. Some of these variables might include the skill of the operator, the day of the week, time of day, the weather or the temperament of the man's wife on the night before. So many uncontrollable factors in a welding operation could only result in poor weld quality, repeated repairs, and an over-all lack of reliability of the product. Thus, it was necessary to improve both equipment and process control, and an automatic unit for fusion welding was installed.

Process control, however, was, and is, a tougher problem. Missile-case sections must fit, surfaces must be clean, and welding speed and wire feed must be closely adjusted to have control of the process. To have a running check —even in addition to the x-ray inspection of each weld – tensile specimens are cut from cylinder end-trim from across the two longitudinal fusion welds. These are heat treated with a missile case.

The resistance seam-welding process, which is employed in welding the end closures to the rolled-and-welded cylinder, did not have quite the rocky beginning as did fusion welding – at least from an equipment standpoint. However, the process was not without major problems in defining and correcting the variables which led to poor quality. For example, we had to be constantly on the alert to keep the faying surfaces clean, and also had to make certain that the domes fit into the cylinder. Then, too, the quality of the sample welds did not correlate with the quality of the welds in the actual motor cases, and there were defects (inclusions, porosity and the like) near the weld nugget. These, and other problems, had to be solved before consistent welds could be produced.

One of the most troublesome problems is abrasive grit on the surfaces of either the mating dome or cylinder parts. It can score the parts and cause cracks or excessive porosity in the weld. Therefore, the faying surfaces must be scrupulously clean.

The fit of the domes, which is controlled by the sizing of the cylinder, helps to maintain

close tolerances and produce reliable welds. The requirement of the sizing operation did point up the need for an expander so cylinders could be sized to the proper tolerance.

When resistance seam welding high-hardenability steels such as A.I.S.I. 4340, the cooling rate of the nugget is critical. It was necessary to control both the preheating and postheating current cycles very closely to avoid weld cracks.

The problem of test welds not being representative of those produced in motor cases was a bit more subtle than the others. Settings which produced a good test weld resulted in welds with very little penetration ("paste welds") in the motor case. It was determined that the current sufficient to make the test weld was considerably reduced by inductive losses. These were caused by the magnetic material of the motor case being in the throat of the welding machine when domes were being joined to the cylinder. To correct the problem, it was necessary to simulate motor-case conditions in the welder to produce comparable results in both the test and motor-case welds. When this was done, machine settings were readjusted accordingly. Welds in motor cases now have a very consistent strength level, ranging between 230,000 and 250,000 psi.

Better Heat Treating Practices

After complete assembly, the motor case is heat treated. During development of the proper heat treating sequence it was learned that practices recommended by suppliers were not all that the doctor had ordered. As a consequence, we had to modify the austenitizing process and choose a tempering treatment which increased the resistance to cracking even though we had used the same steel at the same strength level successfully for other applications. We now heat treat the motor cases by austenitizing them at 1550° F. for 90 min. in an endothermic atmosphere, followed by an oil quench and tempering for 6 hr. at 400 to 500° F. Tensile coupons are heat treated with every motor case to provide control for this process.

A Different Practice Evolves

In this highly competitive motor-case business, the individual companies are trying to "build a better mousetrap". As improvements in process control develop, the potential of interchanging fabrication sequences becomes quite feasible. For example, we have devised a practice opposite to that described previously – the major parts of the motor case can be heat treated before assembly. This change was possible primarily through the development of a new piece of equipment, the long-arm resistance seam welder. It is shown in Fig. 2. With this equipment, the length of the motor case can be spanned to weld the closed dome in place.

Fig. 2 – "Long-Arm" Resistance Welder

Now, we have better control of distortion during heat treatment thus reducing the amount of machining needed when it is completed. To accomplish this, however, resistance seam weld settings had to be adjusted so that the metallurgical properties of the heat treated material were not detrimentally affected. It was also necessary to add a tempering treatment (400 to 500° F.) after welding. Motor cases fabricated by this technique have been demonstrated in every way to be as strong and as reliable as the conventionally treated motor cases. Since they also cost less to produce, we are taking steps to produce missile cases by this new method as much as possible.

In conclusion, it should be emphasized that no specialized machining or forming operations are required for the roll-and-weld construction which we use at Douglas. We are reserving methods such as shear forming of cylinders from rolled rings, and contour milling of end closures, for second-generation motor cases, and are now developing fabrication and heat treating procedures for materials of much higher strength.

Heat Treating Stainless Steel Tubing and Wire

*By C. H. VAUGHAN**

Five types of furnaces – salt bath, bell, wire-mesh belt conveyor, roller-hearth conveyor, and muffle tube – are used in annealing stainless steel wire and tubing. This article discusses the advantages and limitations of each type. (J23, W27; SS, 4-60, 4-61)

TUBING AND WIRE of stainless steel – we can also include related materials such as Inconel, Monel, nickel, Hastelloy and many other special-purpose alloys – can generally be classified into two annealing groups. In the first are those alloys such as the entire series of austenitic stainless steels that must be annealed at 1900° F. or above and then cooled fast or actually quenched. Conversely, the metals in the second group (such as the ferritic stainless steels and nickel) merely require heating to 1500° F. (or higher); cooling may be either fast or slow. In most instances, however, both of the annealing treatments must be performed in a single furnace. Thus, the high-temperature limit and the required speed of cooling will probably dictate the design of the equipment to be used.

Remarks on Atmosphere

Before discussing specific furnace equipment, a few words should be said about atmospheres. Generally speaking, either dissociated ammonia or hydrogen, with dew points controlled to −50° F. and below, is used for bright annealing. However, the simple exothermic atmospheres will maintain bright surfaces on most of the alloys which do not contain chromium. On annealing and pickling lines, in fact, the normal products of combustion, maintained on the oxidizing side, are all that is needed for protection. In salt baths, the molten salt acts as the agent for both heat transfer and surface protection during all stages of treatment.

For bright annealing, dissociated ammonia is, of course, the lowest-cost atmosphere. However, in wire and tube, where the gages are very light, there is a possibility for embrittlement. Though this embrittlement was originally thought to be the result of nitriding by the residual or undissociated ammonia in the atmosphere, the same problem occurs when the atmosphere does not have even a trace of residual ammonia. Subsequently it was found – and it is the subject of a patent – that a substantial increase in the dew point, though it causes a definite discoloration of the material, will prevent embrittlement†.

When embrittlement occurs, it penetrates very slowly after the initial attack whether the material is light or heavy gage. In most of the rundown or process gages, the penetration is so small that it can be tolerated. However, on the very light gages it can become serious and should be prevented by the use of pure hydrogen as a protective atmosphere.

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*Assistant Vice-President, Electric Furnace Co., Salem, Ohio.

†The patent (No. 2,703,298) indicates that for annealing at 1950° F., a dew point of 0° F. is suitable; for annealing at 2050° F., +10° F. can be used.

Furnaces for Heat Treating

There are primarily five types of furnaces – salt bath, bell (or removable cover), wire-mesh belt conveyor, roller-hearth conveyor, and muffle tube – in general use today. The choice lies mostly with the alloy to be treated and the results desired. Each type of furnace has its limitations and each has its purposes.

The salt bath furnace, for instance, handles coiled wire quite ably at almost all the temperatures required in treating the stainless alloys. It is adapted to quick quenching as well and can be built as a small-capacity unit with manual handling of the material (as Fig. 1 shows) or as a semicontinuous operation. In the latter arrangement, the various stages of the treatment (cleaning, heating, quenching, pickling, washing and drying) are set up in sequence beneath an overhead conveyor.

While the use of salt as both a heat transfer and protective agent does prevent scaling, it does not completely eliminate oxidation. As a consequence, the material is always slightly discolored by an oxide, but the coating is easily pickled off without any appreciable metal loss. For these reasons, salt bath equipment is particularly adaptable to process anneals but is very seldom used for finish anneals.

Furnaces of the bell and wire-mesh belt conveyor type are used for coiled wire, necessarily being restricted to those alloys that can tolerate, or that actually require, a slow cool. Figure 2 shows the charging end of a conventional furnace with a belt conveyor of wire mesh; it can treat nickel wire at approximately 275 lb. per hr. If nickel is being processed exclusively, the furnace atmosphere is the cheapest variety, that is, the exothermic type. When either dissociated ammonia or hydrogen is used, this same furnace (electrically heated, and with a high-purity brick lining or metal muffle) will bright anneal chromium and chromium-nickel stainless. To conserve the more expensive atmosphere, this type of equipment often uses sloped charging and discharging vestibules.

Equipment of the roller-hearth conveyor type can be used for large production runs (as much as several thousand pounds per hour, in fact). It is particularly adaptable to an open-fired annealing operation where heat treatment will be followed by pickling. Such equipment is versatile; it can be fitted with automatic quenching for an austenitic alloy, or can be provided with runout tables for slower cooling. Roller-hearth units can also be altered to use indirect heating, attached cooling chambers, and atmospheres for the nonaustenitic group of alloys.

For uniformity and quality, most fine and medium-gage wire is finish-annealed in fur-

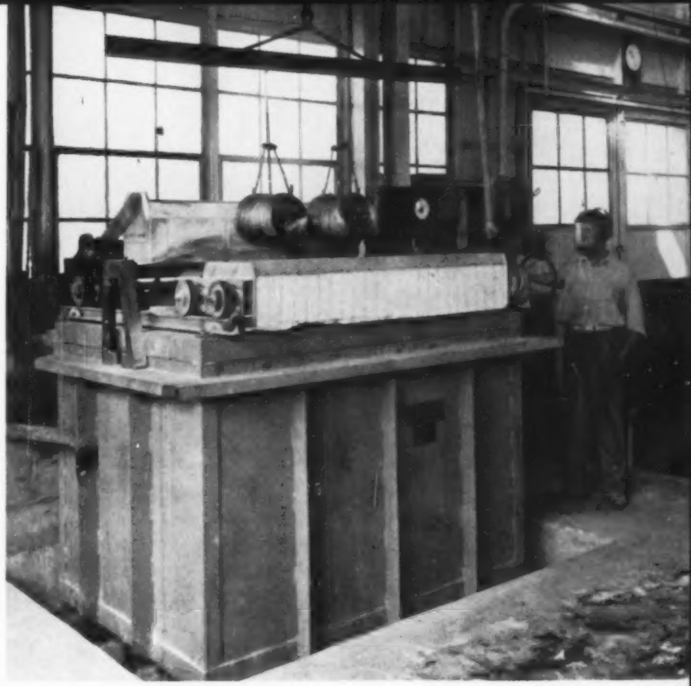
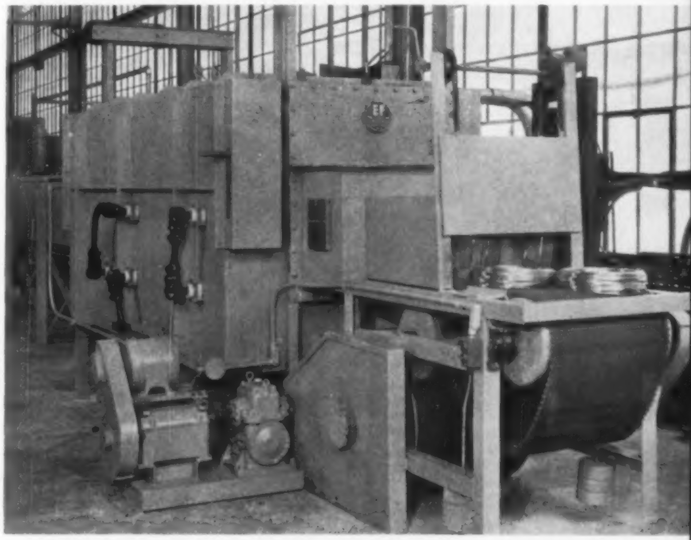


Fig. 1 – Salt-Bath Furnace for Annealing Fine (0.020 In.) Nickel-Chromium Wire at 1950° F. Salt baths are particularly useful for process annealing stainless steel tubing and wire on either a batch or continuous basis

Fig. 2 – Wire-Mesh Belt Conveyor Unit for Annealing Coiled Wire. This type of furnace (and the bell furnace as well) are limited to alloys that require or can tolerate slow cooling



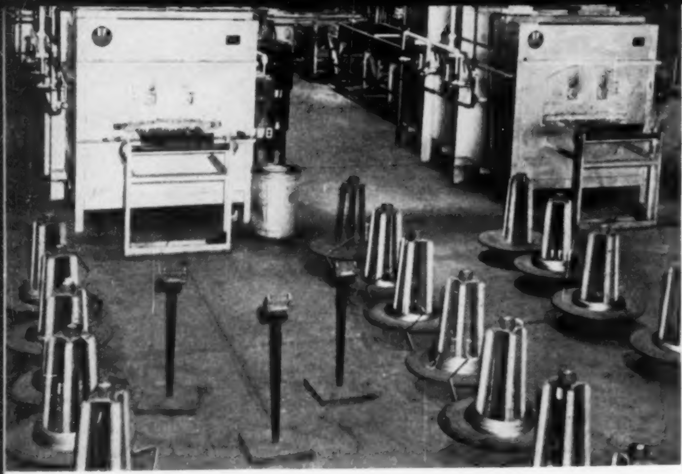
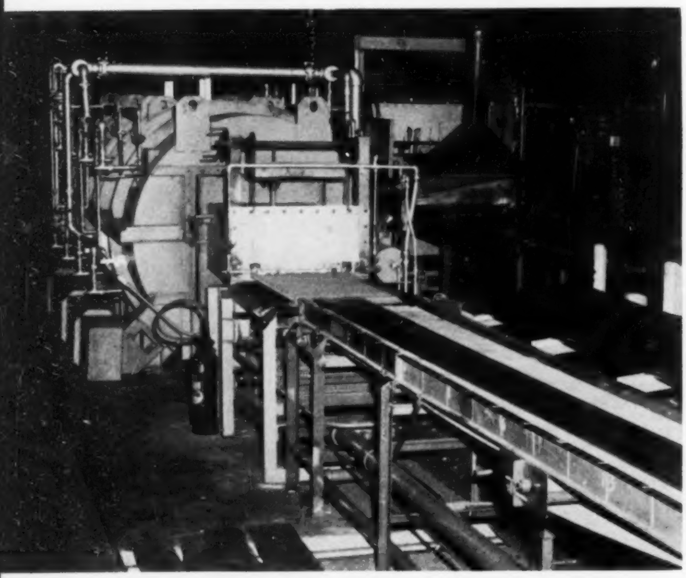


Fig. 3 – Two Annealers of the Muffle-Tube Type Shown Here Are Part of an Installation of Five Furnaces Which Can Process 4,000,000 Ft. of Wire Every Hour

naces employing muffle tubes. In such equipment (Fig. 3), the wire is uncoiled in multiple strands and drawn through individual, small-diameter tubes which extend through both the heating and cooling chambers. Since heating and cooling are very rapid and uniform, brightness and mechanical properties can be easily controlled.

A fairly safe estimate of the ability of this type of equipment to produce fully annealed wire can be made by applying the rule of thumb, "1 lb. of wire per hr. per ft. of effective heating tube length". For example, a furnace having 25 tubes, a 10 ft. heating section, and an adequate cooling section will fully anneal about 250 lb. of wire per hr.

Fig. 4 – This Unit for Annealing Tubes Uses Separate Wire-Mesh Belts in the Entry, Exit and in the Furnace. Such an arrangement reduces tension in the furnace conveyor



Unfortunately, muffle-tube furnaces require a large investment in coiling and uncoiling equipment and controls. However, they completely eliminate both the expense of pickling equipment and operations, and allow closer control of physical properties.

Process Annealing May Be Needed

When considering tubing and pipe, we will first need a rather brief look at process annealing. Generally, this process consists of an oxidizing anneal, followed by pickling. The oldest, simplest and lowest-priced equipment is the car bottom or hearth-type furnace, usually fired with gas or oil. With these units of conventional design, lift trucks are generally employed for loading and unloading the material and transferring it rapidly to quenching units.

The roller-hearth furnace is extensively used for process and finish annealing loads of all sizes. Since the material is loaded in a single layer on the roller conveyor, the rate of travel, and thus the rate of transfer from the hot section to the cold section, is reasonably rapid. In fact, light and medium-wall tubing of the Type 300 stainless series can be cooled in air fast enough to maintain austenitic structures down to room temperature.

Roller-hearth conveyor furnaces, when electrically heated and equipped with heating chambers lined with high-purity refractories, have also proved satisfactory for bright-finish annealing operations. An atmosphere of dissociated ammonia or hydrogen is employed.

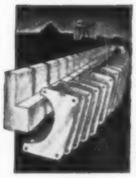
The muffle tube furnace can be used as a continuous unit and as a batch furnace. In a continuous unit, the tubing is drawn through the heating and cooling chambers under atmospheric protection. In the batch-type unit, a rack conveys cut lengths of tubing first into the heating chamber, then into the cooling chamber.

As an all-purpose unit, a furnace which uses belt conveyors of wire mesh seems to be the most practical for bright-finish annealing when production need not be large. Figure 4 shows the entrance of such a unit. To reduce tension in the furnace conveyor, the unit employs separately driven entry and exit conveyors which travel at the same speed as the furnace conveyor. Such equipment is equally adapt-

able to gas firing (with a muffle) and to electric heating with or without a muffle. Since loads are generally light, work can be heated to about 2200° F., the limitation usually being the ability of the belt conveyor to resist heat.

In Conclusion

Here, we emphasize that the preceding discussion touches only the high spots. It is merely intended as a brief outline on which to build detailed studies of particular production problems. In such planning, full consideration must be given to the treatments desired, the range of alloys to be handled, the production capacity required, individual plant conditions, labor usage, the demands of the market, space availability, and many other considerations.



Short Runs

Automatic Production of Ring Gears

In recent years rising materials and labor costs have forced metalworking plants to seek out new and improved ways of processing metals to improve efficiency. One good way, of course, is to install high-speed automatic equipment.

This was the course taken by Eaton Mfg. Co., whose million-dollar forging installation for automatic production of steel ring gears recently went into operation at its Marion (Ohio) Div. The complete set-up consists of a 25-ft. diameter rotary furnace with automatic charging and discharging equipment, gravity conveyors leading to a 6000-ton mechanical press, and automatic manipulators which load the heated billets (either 4718H or 8720H steel) onto the first-stage buster die and then transfer the semifinished part to the blocker and the finish die. This equipment replaces smaller hammers in the plant which needed 25 to 40 blows to forge the same gear. In addition to increasing production, the press turns out ring gears of higher quality. An added benefit is that the amount of scrap is appreciably reduced, since the billet size is smaller and ring gear rejections are much lower.

Automatic Rotary Furnace

The rotary hearth furnace heats the 6 or 7-in. square billets (varying in length from 5½ to 12⅝ in.) to 2400° F. at a rate of 150 pieces per hr. (18,000 lb. per hr.). Heating is done by 41 radiant burners operating in three zones of the furnace. These burners are supplied with a gas-air mixture, automatically proportioned. The control system is operated in conjunction with platinum/platinum-rhodium thermocouples to maintain furnace temperatures at preset points by regulating the rate of gas flow to the burners. Fuel mixtures can be further adjusted to provide a neutral or slightly reducing or oxidizing atmosphere. For most forging work, a slightly reducing atmosphere is preferred since it minimizes scale formation.

The automatic charging and discharging mechanism consists of a reciprocating carriage and two water-cooled manipulators. Loading clamps pick up a cold billet from a charge conveyor, raise and advance the billet into the furnace and then place it on the hearth. As the charge manipulator releases the work and is ready to retract, the unloading clamp picks up

a hot billet and transfers it to the discharge conveyor.

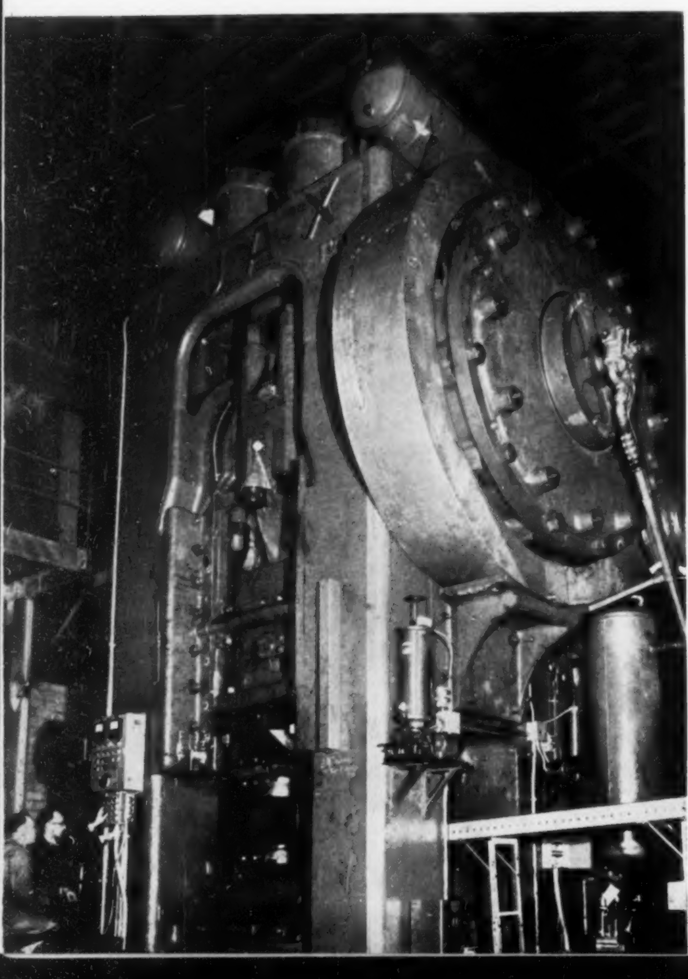
A typical cold billet (a 7-in. cube weighing 100 lb.) is in the furnace about 45 min. in heating to the forging temperature of 2250° F. It is in the first zone of the furnace for 5 min. and attains a temperature of 1200° F. In the second zone it reaches 2200° F. in about 30 min., and in the third, the center and surface temperatures are equalized at 2250° F. in about 10 min.

High-Speed Forging Press

Heated billets ready for forging travel down the inclined conveyor and are loaded onto the first press die by an automatic side-loader and manipulator designed and built at the Eaton Technical Center. The manipulator then transfers the semifinished forging to the second die and to the finish die, and finally removes it from the press.

The 6000-ton press (Fig. 1) is currently producing ring gear forgings ranging from 13 to 18½ in. in diameter and weighing 40 to 150 lb., but it can turn out a wide range of other forgings such as clutch plates and helical gears.

Fig. 1 – High-Speed 6000-Ton Mechanical Press Forges Ring Gears and Other Parts Automatically in Three Stages. The press weighs 700 tons and is driven by a 400-hp. motor



Its huge frame – a one-piece, uncored steel casting weighing 470,000 lb. – is made like a rolling mill housing for maximum strength and minimum stretch. The die table of the press measures 70 in. across and 74 in. deep; it provides straight-through access.

Driving power of the large flywheel and the 400-hp. motor is transmitted to the backshaft through a friction hub which slips when the allowable torque has been exceeded to prevent damage to the press. Slippage can occur many times without varying the torque or affecting the overload device. During operation, the press can deliver 35 blows per min. through an 18-in. stroke.

Provision is made for "inching" the press for die setting by intermittent engagement of the clutch with the flywheel running at slow speed and no current to the motor. A strain gage is installed on the face of the frame to indicate percentage of full load existing during a work stroke. Thermocouples mounted in the major bearings actuate an alarm if any of these points exceed a preset temperature.

In the production of ring gear forgings, rolled billets of 4718H or 8720H steel are sawed to length, analyzed spectrographically and spot checked for surface roughness and dimensions. Billets are loaded onto conveyors leading to the rotary furnace with the sawed faces in a horizontal plane so that the flow lines in the finished ring gears are radial. Any other billet orientation would produce earing and a nonuniform flow pattern. A 40% graphite-grease mixture is currently used as a die lubricant; this will soon be replaced by a colloidal graphite-water dispersion which will be sprayed on automatically. Die life on the big mechanical press has been appreciably increased – Eaton is getting 4000 to 6000 forgings per finish die versus 1000 to 1500 blows per die on smaller hammers producing the same ring gear.

After forging, the finished ring gears are trimmed (hot), annealed at 1700° F. for 30 min. (to Bhn. 197, maximum) for improved machinability, cleaned, and shipped to the customer for finish machining and carburizing. At Eaton, gears are gas carburized at 1700°F. to give a case depth of 0.050 to 0.065 in. and are then direct quenched into oil, and tempered at 300 to 350° F. for 2 hr.

Revere helps "fit the metal to the job"

AND A COMMUTATOR MANUFACTURER SAVES ON BOTH MATERIAL COSTS AND OVERALL COSTS WHILE PRODUCING A SUPERIOR PRODUCT

The hub of the small commutator you see above originally was made of a ferrous metal. Certain problems cropped up due to the fact that the rod from which the hubs were fabricated, not only had to be drilled, but it also had to be able to withstand a flanging operation. The engineering department of Dayton Precision Manufacturing Company called in one of Revere's Technical Advisors for consultation.

After a thorough study of the problem Revere Brass Rod of a certain alloy was recommended and samples were furnished. The machinability of the rod was found to be outstanding, being readily and speedily drilled. Also it withstood the flanging operation . . . a set of manufacturing conditions where only brass, the right kind of brass, outshines all other metals and alloys.

Final score: The low first cost of the brass rod, plus its superior machinability, resulted in a more satisfactory product without the penalty of higher costs. A further advantage to the manufacturer was the added sales appeal of the brass hub.

And there you have another example of how Revere in collaboration with the manufacturer helped, "fit the metal to the job," which resulted in a better part at the least possible cost. Why don't you take advantage of this kind of service?

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Circle 445 on Page 48-B

CORRESPONDENCE INVITED ON ANY METALLURGICAL SUBJECT

LETTERS TO THE EDITOR

Temperature Conversion Formulas

WOOD-RIDGE, N.J.

Your readers may be interested in the following temperature conversion formulas which are useful in the absence of a conversion table or slide rule:

$$°F. = (2)(°C.) - (0.2)(°C.) + 32$$

$$°C. \cong °F./2 + °F./20 + °F./200 - 20$$

The first formula is exact, while the second is accurate within a few degrees over a wide range of temperatures. The operations are reduced to multiplication or division by two, which can be done mentally, followed by addition.

JULIAN I. KYCIA
Metallurgist
Wright Aeronautical Div.
Curtiss-Wright Corp.

Strains in Embrittled Tank

BEAUMONT, TEXAS

Though the photograph shown on this page is approximately 30 years old, it should be interesting to your readers from an educational, if not from an industrial, point of view. When examining a riveted caustic mixing tank for embrittlement, we etched the steel plate for strains in accordance with directions described by A. Fry in *Stahl und Eisen* in 1921. As is evident, the etching solution, which consisted mainly of a strong hydrochloric solution of copper chloride, revealed the "strain action lines" (so called by Dr. Fry) very nicely.

H. M. WILTEN
Instructor
Dept. of Mechanical Engineering
Lamar State College of Technology

Some Reagents Explode

HARRISBURG, PA.

We would like to call your attention to an explosion hazard which can occur with the use of a well-known etching reagent for nickel. The solution contains nitric acid, acetic acid, and acetone, most commonly as equal amounts of each.

The hazard was first observed in our laboratory. A closed bottle containing 40 ml. of 75% acetic acid (AR grade), 40 ml. of acetone (CP grade) and 40 ml. of concentrated nitric acid (AR grade) exploded approximately 4 hr. after it was prepared. The explosion, which may occur anywhere from 1½ to 6 hr. after mixing, has a force considerably in excess of that which would be expected merely from heating. For example, 120 ml. of solution in a closed glass bottle was placed in a heavy rubber pail having walls between ¼ and ½ in. thick. Only a portion of the top was covered. Two hours and 45 min. later, the bottle exploded with sufficient force to break large pieces out of the pail.

If the solution is prepared, even in small quantities, and placed in an open test tube, the reaction becomes so vigorous after several hours that the solution is discharged from the test tube, although no explosion occurs. This will happen without acetic acid being present.

HARRY A. FOX, JR.
MARTIN S. FRANT
AMP Inc.

Going to the Dogs

SANTA MONICA, CALIF.

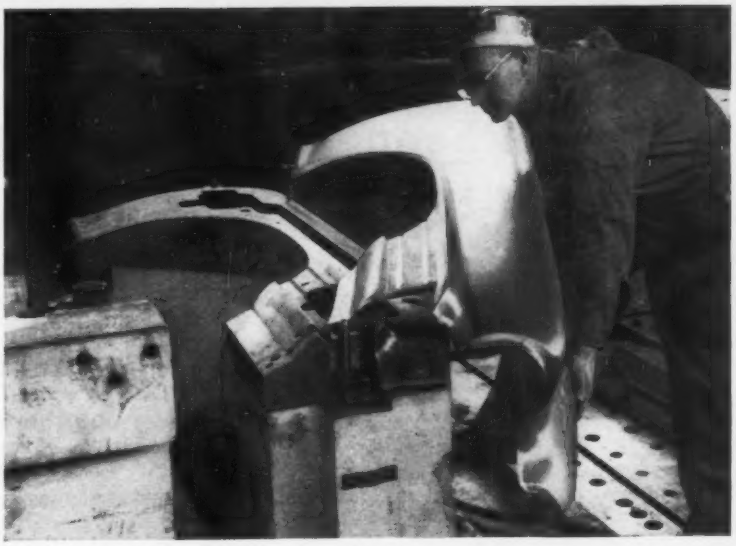
We often hear the expression "Everything is going to the dogs". What better proof than in the electron micrograph below of a ferrite phase found in ultrahigh strength steel tempered at 500°F. The outline of a scotty is clearly seen at 18,500 ×.

AUSTIN PHILLIPS
Materials Research & Process Eng.
Douglas Aircraft Co.

Tool Steel Topics

BETHLEHEM STEEL COMPANY, BETHLEHEM, PA.

Auto fenders trimmed with dies made from water-hardening tool steel



These photographs, taken at Mardigian Corporation, Warren, Mich., show the use of Bethlehem carbon water-hardening tool steel in trim dies for automobile front fenders. The dies, hardened to Rockwell C 62-64, trim 20-gage cold-rolled sheet steel. In the picture above, 15 sections of the tool steel, bolted into the casting, are ready for "Kellering." The companion picture was taken after the tool steel sections were machined to contour and heat-treated, making a completed form-and-trim die.

Engineers at the Mardigian plant reported fine results with Bethlehem carbon water-hardening tool steel. They especially liked its excellent machinability and uniform response to heat-treatment, plus the fact that modification could be easily accomplished by welding.

Due to their carefully controlled hardenability, Bethlehem carbon water-hardening grades deliver long service in applications calling for high shock-resistance. They have good resistance to wear, and plenty of toughness to resist the effects of cold battering.

Your Bethlehem tool steel distributor has a wide range of carbon water-hardening steels in stock. He will be pleased to meet your needs. Get in touch with him today.

BETHLEHEM TOOL STEEL ENGINEER SAYS:

Avoid Early Failure of Cutting Tools by Removing the "Feather" Edges

When a grinding wheel crosses a tool edge, a small burr or "feather" remains on the edge, no matter how carefully or properly the grinding operation may have been carried out. If the tool is used with the feather-edge, it is equivalent to using a tool having a dulled cutting edge. Obviously, production from such a tool will not be as high as from a similar tool with sharp edges. Many machinists, recognizing this, carry a hand stone which they use in removing the feather from the cutting edges. However, the most practical and positive method of removing the feather from the edges of ground tools is by fiber brushing on a rotary wheel.

By removing the feather-edge before a tool is placed in service, the user is assured of increased production because the edges of the tool do not dull as rapidly.

Circle 446 on page 48-B

Platinum Metals . . .

(Continued from p. 90)

corrosion resistance. In one example already announced (see *Metal Progress*, May 1959, p. 117), as little as 0.1% (by weight) of palladium added to titanium considerably increased its corrosion resistance. (Though other members of the platinum family also produced about an equivalent effect, palladium was used because it was the least expensive metal of the group.) Thus alloyed, titanium resists boiling solutions of reducing acids (such as hydrochloric and sulfuric acids) without impairing the well-known resistance of titanium to oxidizing acids (such as nitric acid). Total cost of the 0.1% paladium addition amounts to only $0.28 per lb. of titanium — a very small percentage increase in the cost of the base metal.

Just as spectacular, although considered to be not as practical, is the recent Russian work by N. V. Tomashov and colleagues. By adding small amounts (0.1 to 0.9%) of platinum and palladium, they were able to increase considerably the resistance of stainless steels (such as 18% Cr, 9% Ni; or 27% Cr) to sulfuric acid. Up to now, costs outweigh advantages, but further study may establish an entirely different conclusion.

Chemical Process Equipment

Ever since the early introduction of a platinum boiler (for concentrating dilute sulfuric acid), platinum has played a major role in chemical processing equipment. Its corrosion resistance at high temperature, ease of fabrication, and guarantee of product purity make platinum very useful in such service. Today, stills, autoclaves, condensers, heat exchangers, tubing and many other types of equipment are made of precious metals, with the trend toward platinum-lined base metal becoming apparent where the base metal can be economically clad. Where requirements for corrosion resistance are not quite as severe, palladium, with its comparable ease of fabrication, is also widely used.

Surface Film Formation

Platinum and rhodium are virtually free from oxide (or other type of film) on their surfaces, and the

Platinum Metals . . .

other members of the family show only small amounts of surface oxides over narrow and specific temperature ranges. As a result, these metals and their alloys can be used where a bright metallic surface must be maintained during long-time exposure to oxidizing or tarnishing environments.

An electrical contact is one example. It must be able to make contact on closing of a circuit, carry circuit without overheating, and break contact (to interrrupt the current) without undue deterioration. Oxidation and sulfidation obviously promote contact resistance, overheating and destructive arcing, if not complete interruption of the circuit. Where low and constant contact resistance must be maintained, complete immunity to film formation is essential. It is in this area that the platinum metals find the most use.

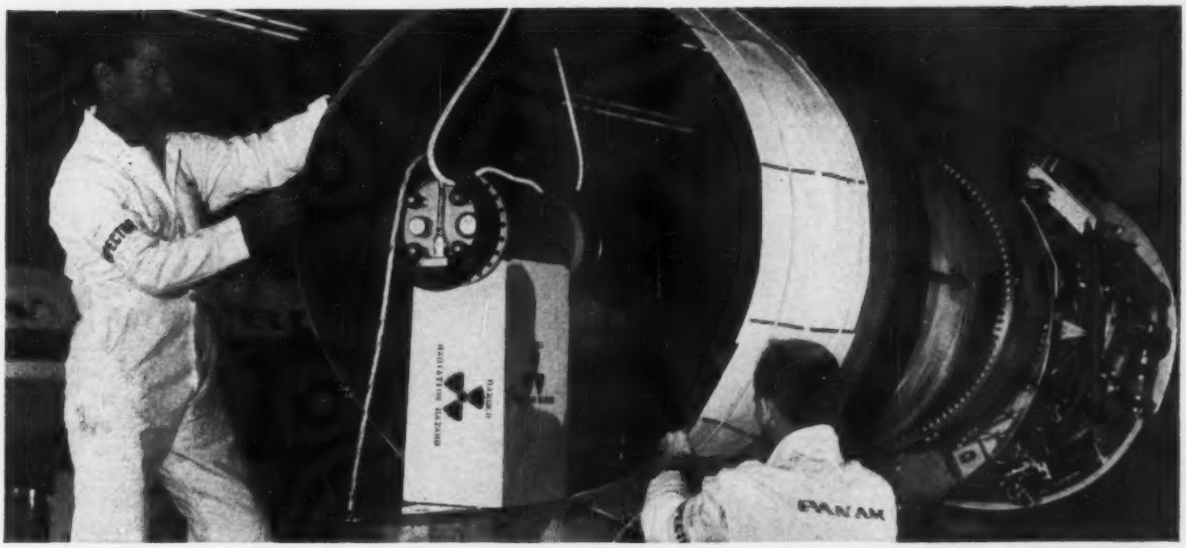
Platinum contacts are used in telegraph transmitters, alarm systems and temperature controllers; palladium, in relays for telephones and missiles; platinum-iridium, in sliding contacts where wear resistance is also required; and rhodium or rhodium plate, in radio frequency circuits as well as sliding contacts.

Three Uses for Rhodium

Printed circuits require a metal that can be "printed" easily, has good conductivity, and resists deterioration in service. While all of the platinum metals readily offer the last of these characteristics, rhodium is preferred for the other two requirements. It is readily plated, and has the highest conductivity (35% of copper) of the platinum group.

Rhodium is also useful in such items as searchlight reflectors because of its reflectivity and resistance to heat and abrasion. With its high surface hardness, it can be cleaned mechanically without any impairment to its reflectivity.

Because rhodium maintains a white lustrous appearance in oxidizing and tarnishing environments, it is used to protect the surface of precision apparatus and for eye appeal in scientific instruments and camera fittings. A rhodium deposit as thin as 0.000015 in. is adequate protection against tarnish under ordinary conditions. *(Cont'd on p. 120)*



Pan Am inspectors position Kodak Industrial X-ray Film and 360° x-ray unit to radiograph jet engine thrust ejector.

It throttles the roar of a 16,000-lb. thrust

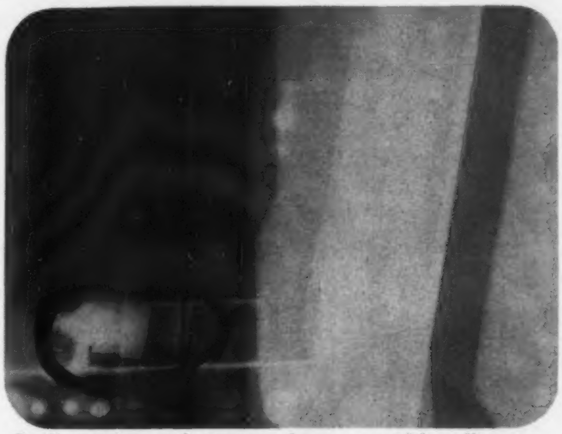
Thrust ejectors on jet engines must be examined every 400 hours. Pan American Airways does it radiographically—cuts inspection time more than 90%.

To remove the floating skin on a jet thrust ejector and check its insides takes a lot of expensive man-hours. But Pan Am gets the answer—now—in one-tenth the time.

By wrapping both Type AA and Type M Kodak Industrial X-ray Film around the ejector, a single exposure with a 360° x-ray head provides inspection of both thin and thicker sections of the unit.

This is another example of the way radiography saves time and guards quality. It inspects enclosed assemblies. It examines castings for inclusions, voids and shrink. It proves the soundness and continuity of welds. And in every case provides a record for reference.

Radiography can save you time, save money, and build a reputation for high-quality work. If you'd like to discuss how it can help you, get in touch with an x-ray dealer or write us for a Kodak Technical Representative to call.



Radiograph reveals structural parts sound but discovers an air pipe clamp is broken.

Now . . . Ready Pack in ROLLS and SHEETS Kodak Industrial X-ray Film, Types AA and M in 200-ft. rolls (16mm, 35mm, 70mm) and sheets (8 x 10, 10 x 12, 11 x 14, 14 x 17).

- No darkroom loading—film sealed in a light-tight envelope.
- Just place Ready Pack in position and expose.
- Film protected from dust, dirt, light and moisture.
- In the darkroom—remove film from envelope and process.

EASTMAN KODAK COMPANY

X-ray Sales Division **Rochester 4, N. Y.**

Kodak
TRADEMARK

 Circle 450 on Page 48-B

Platinum Metals . . .

High-Temperature Stability

Platinum and rhodium show exceptionally little weight loss through formation of volatile oxides at temperatures near their melting points (3212 and 3500° F., respectively). Because of this characteristic, both metals can be used in high-temperature applications, many of which have already been mentioned. In addition to these, the platinum metals may serve as protective coatings for nose cones of missiles, as fuel nozzles for jet engines, and as oxidation-resistant coatings for metals such as tungsten and molybdenum. Already, they are being used in furnace windings and ignition systems where designers need reliable performance at high temperatures over long periods of time.

Platinum and its alloys are particularly suitable for electric heating elements in furnaces operating between 2200 and 3100° F. under oxidizing conditions. Such furnaces can be run constantly for long times as high as 2750° F., and rhodium alloy windings for special applications have been used up to 3300° F. Laboratories in particular require those high temperatures for combustion methods of analysis, fusion point determinations, thermocouple checks, and tests of mechanical properties at high temperatures.

Among ignition applications, platinum alloyed with 4% tungsten is used as the electrode on spark plugs for high octane ignition. The fibrous structure of this powder metal alloy resists damage by lead; and with a recrystallization temperature higher than the service temperature, the metal also resists grain growth.

Purity and Reproducibility

The thermoelectric and electrical properties of platinum, together with its durability, make the metal ideally suited to thermocouple and resistance thermometry applications where wide temperature ranges and long exposure to unfavorable environments are encountered.

The two most widely used thermocouples consist of pure platinum coupled with the platinum-10% rhodium alloy and pure platinum coupled with the platinum-13% rhodium alloy. Both metal and alloys must be

Circle 453 on Page 48-B

Platinum Metals . . .

exceptionally pure. Properly used, the couples are usually stable and long-lived over a wide range of temperatures. Results are highly reproducible as well. These couples can withstand continuous service at 2550° F., intermittent service at 2900° F. and quick immersion in molten steel at 3100° F.

Recently, the 5% rhodium alloy of platinum has been paired with the platinum-20% rhodium alloy to form a new type of thermocouple. Compared to the other two couples already mentioned, it has greater hot strength and a higher melting point. It can withstand continuous service at 3100° F. and has an absolute limit of 3315° F. for one-time use. Engineers employ this type to measure temperatures of open-hearth furnace roofs, and in the manufacture and testing of refractories.

Fig. 5 — Basket Woven of Platinum-10% Rhodium Wire. It is used in the chemical processing industry

Resistance Thermometry

There is a simple and direct relationship between the electrical resistance of platinum wire and its temperature. This relationship, along with its other properties (stability and reproducibility) makes the metal an ideal selection for resistance thermometry. It is accurate to 0.00018° F., operates through a wide tempera-

Circle 454 on Page 48-B

Platinum Metals . . .

ture range, and responds at high speed. Adaptable to gas, liquid and solid measurements, the platinum resistance thermometer is generally accepted as the most accurate temperature measuring instrument available. It has been the primary international standard (for temperatures below 1167° F.) for over 30 years.

With today's outer space applications and need for fast and accurate sensing elements, temperature transducers must be rugged, compact, and able to produce large signal outputs without amplification. The platinum resistance thermometer, in one form or another, meets these stringent requirements; it serves in industries as varied as aircraft, power stations, chemicals, and the storage, processing and transportation of food.

Some Other Properties

One of the interesting characteristics of palladium, its ability to absorb and diffuse large amounts of hydrogen, is employed in devices for hydrogen determination, gas separation, and the preparation of pure hydrogen. (These usually contain palladium membranes which selectively absorb and diffuse hydrogen.)

Magnetic Properties

Certain of the platinum-cobalt alloys are well-known for their outstanding magnetic properties. Only recently has the alloy containing equal numbers of atoms of each element (76.7% Pt, 23.3% Co by weight) been fully studied. When properly heat treated, this alloy is an excellent material for powerful permanent magnets. Exhibiting a very high coercive force and maximum energy product, it offers a BH (max.) of 9.2×10^6 gauss-oersteds, almost double that realized with Alnico V. In addition, unlike most base-metal magnetic alloys (which are relatively brittle), this platinum-cobalt alloy can be readily machined, rolled, or drawn before heat treatment.

The above characteristics imply great possibilities which are only now beginning to be explored. Wherever volume restriction is a factor, whether it be in satellite components or in hearing aids, the platinum-cobalt alloys are worth consideration.

Circle 456 on Page 48-B

PERSONAL MENTION

Raymond B. Hoxeng

Raymond B. Hoxeng has been appointed director of research for American Steel and Wire Div. of United States Steel Corp., situated in Cleveland.

Born in South Dakota, he studied at Yankton (S.D.) College, Iowa State College, the University of Pittsburgh and Case Institute of Technology, and he holds a doctorate in physical chemistry. From 1942 to 1945, he was a research associate on the Manhattan Project at Iowa State College and the University of Chicago. He then conducted corrosion research at the Aluminum Co. of America's research laboratory in New Kensington, Pa., for the next two years. Turning to education, he was a professor and lecturer on corrosion at Case Institute of Technology until coming to U.S. Steel in 1951 as a research associate in the applied research laboratory. In 1955 he was named chief of the chemical-metallurgy division and a year later became assistant to the director, organization planning, the post he leaves to accept his new job.

Married, with two children, he is active in church and civic affairs, and is an elected commissioner of Mt. Lebanon (Pa.) township.

Harry S. Blumberg

Now a consulting metallurgist in the area of steam power plants, petroleum refineries and chemical plants in New York, Harry S. Blumberg was chief metallurgist for M. W. Kellogg Co., Jersey City, N.J. for more than 30 years until his retirement in 1957.

One of his earliest jobs in 1916 was at the Illinois Tool Works where he was assistant to A. G. Henry, one of the founder members of A.S.M. During this time, Mr. Blumberg began what turned out to be a long association with A.S.M. —he worked as a technical proofreader for an early A.S.M. publication under W. H. Eisenman's direction. A member for 43 years, he now holds a life membership. In 1920 he joined Illinois Steel Co. as a metallurgist; two years later he moved to A. O. Smith Corp., then to the Paper and Textile Machinery Co. After becoming chief metallurgist for M. W. Kellogg in 1926, his work included the development of materials for oil refineries, chemical plant processes, fabrication, joining and heat treatment techniques. He was also co-inventor of the "Kelcaloy" and "Pluramelt" consumable hollow electrode method for producing ingots requiring no top or bottom discard (and now used for melting superallows and "exotic" metals). During this time, he also developed (in 1938) the Tempil method for indication of metal and nonmetal working temperatures. (Metal Progress contained the first write-up of the new technique in 1940.)

Married to Isabell Fromert, he has two adopted children—a daughter (and five grandchildren) and a son, now living in Florence Italy.

A former pitcher for a semiprofessional baseball team (he prizes a Milwaukee Journal headline reading "Pitcher Loses One Game in 200"), he now confines himself to less strenuous outdoor pursuits — fishing and boating on the Delaware River near his home in Bushkill, Pa. Another interest is foreign languages.

His society memberships include A.S.M., as noted above, the Iron and Steel Institute of Great Britain (since 1924), A.W.S. and many others.

John J. McGrann — from district manager, Steel and Tube Div. of Timken Roller Bearing Co. in Los Angeles, to assistant manager of tube sales in the Canton, Ohio, home office. **Robert Winder,** a sales engineer in the division's Los Angeles office, succeeds Mr. McGrann as district manager.

Laszlo J. Bonis — from technical director to executive vice-president, Ilikon Corp., Boston.

W. R. Breeler — from general manager of Allegheny Ludlum Steel Corp.'s Dunkirk, N.Y., plant, to president of Allegheny Ludlum International, S.A. with headquarters in Geneva, Switzerland.

Anthony A. Mendes — now branch manager for the North Jersey district of Carpenter Steel Co., Reading, Pa.

Personals . . .

Frank L. Frish – from tool steel product sales engineer to assistant manager of Crucible Steel Co. of America's Chicago sales branch.

Stuart T. Ross – from the aeronutronics division of Ford Motor Co., to vice-president of research and engineering for Brooks & Perkins, Inc., Detroit.

Michael Orehoski – now chief research engineer, metal casting, at the United States Steel Corp. Research Center in Monroeville, Pa.

Paul E. Gage – from branch manager of the Baltimore, Md., division, Kaiser Aluminum Chemical Corp., to sales engineer for the Beryllium Corp., Reading, Pa.

Anthony L. Ascik, operations manager, alloy and metals division, Tennessee Products and Chemical Corp., Nashville, Tenn. – elected vice-president of the company.

O. B. J. Fraser – retired from the International Nickel Co., Inc., as assistant manager of the development and research division after 44 years with the company. He will continue to be active in his field as a consultant.

Daniel J. Lam – now assistant metallurgist in the metallurgy division at Argonne National Laboratory, Argonne, Ill.

Leonard Bernstein – formerly in charge of the metallurgy section of the advanced device department of Hughes Semiconductor, now director of research and development at Alloys Unlimited, Inc., L.I., N.Y.

Elmer E. Weismantel – appointed supervisor of mechanical metallurgy in the research and development department of Beryllium Corp., Reading, Pa.

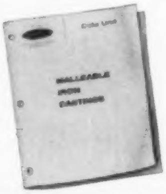
Charles Mangold – now manager of the production department at the American Tool Works Co., Cincinnati, Ohio.

William F. Peschel – from Detroit district sales manager for Ajax Magnethermic Corp. to manager of the induction heating division of Olsen Mfg. Co., Royal Oak, Mich. The company's induction heating sales are represented by **T. E. Olson** of T. E. Olson Co.

Circle 458 on Page 48-B

Post-Forming: New Way to Bigger Savings with Malleable Castings

The ductility of Malleable iron castings permits use of high-speed forming techniques to finish Malleable parts at lower cost. Take advantage of the versatility you get only with ferritic and pearlitic Malleable castings. For a fuller understanding of how Malleable can help you, call any producer that displays this symbol —

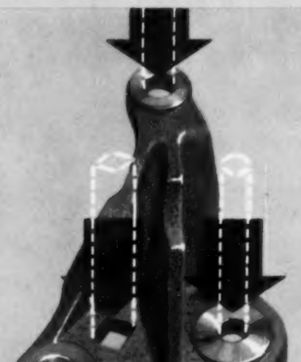


Free Folder describing these techniques is available for your use. Just ask any member of the Malleable Castings Council for Data Unit No. 116, or write to Malleable Castings Council, Union Commerce Building, Cleveland 14, Ohio.

MEMBER
MALLEABLE
CASTINGS COUNCIL

Hot Form It — Hot coining this Malleable transmission part reduces finished cost . . . eliminates three cutting operations required by the previously used steel part.

Roll It — Oil grooves in lawnmower crankshafts and splines in compressor crankshafts are just two of many places where rolling proves more economical than machining.



Punch It — Holes with diameters greater than the thickness of the metal can be punched in Malleable. Two round holes and a square hole are punched simultaneously in this idler arm.

Spin It — Malleable's ductility permits the sleeve and end disc in this ball joint to be held in place by spinning the Malleable housing into a strong, permanent flange.

Get the most for your metals dollar . . . get MALLEABLE

CONNECTICUT
Connecticut Mall. Castings Co., New Haven 6
Eastern Malleable Iron Co., Naugatuck

DELAWARE
Eastern Malleable Iron Co., Wilmington 99

ILLINOIS
Central Fdry. Div., Gen. Motors, Danville
Chicago Malleable Castings Co., Chicago 43
Moline Iron Works, Moline
Moline Malleable Iron Co., St. Charles
National Mall. and Steel Castings Co., Cicero 50
Peoria Malleable Castings Co., Peoria 1
Wagner Castings Company, Decatur

INDIANA
Albion Malleable Iron Company, Muncie Division, Muncie
Link-Belt Company, Indianapolis 6
National Mall. & Steel Castings Co., Indianapolis 22

IOWA
Iowa Malleable Iron Co., Fairfield

MASSACHUSETTS
Belcher Malleable Iron Co., Easton

MICHIGAN
Albion Malleable Iron Co., Albion
Auto Specialties Mfg. Co., Saint Joseph
Cadillac Malleable Iron Co., Cadillac
Central Fdry. Div., Gen. Motors, Saginaw

MINNESOTA
Northern Malleable Iron Co., St. Paul 6

MISSISSIPPI
Mississippi Malleable Iron Co., Meridian

NEW HAMPSHIRE
Laconia Malleable Iron Co., Laconia

NEW YORK
Acme Steel & Mall. Iron Works, Buffalo 7
Frazer & Jones Company Division
Eastern Malleable Iron Co., Solvay
Oriskany Malleable Iron Co., Inc., Oriskany
Westmoreland Mall. Iron Co., Westmoreland

OHIO
American Malleable Castings Co., Marion
Central Fdry. Div., Gen. Motors, Defiance
Dayton Mall. Iron Co., Ironton Div., Ironton
Dayton Mall. Iron Co., Ohio Mall. Div., Columbus 16
National Mall. and Steel Castings Co., Cleveland 6

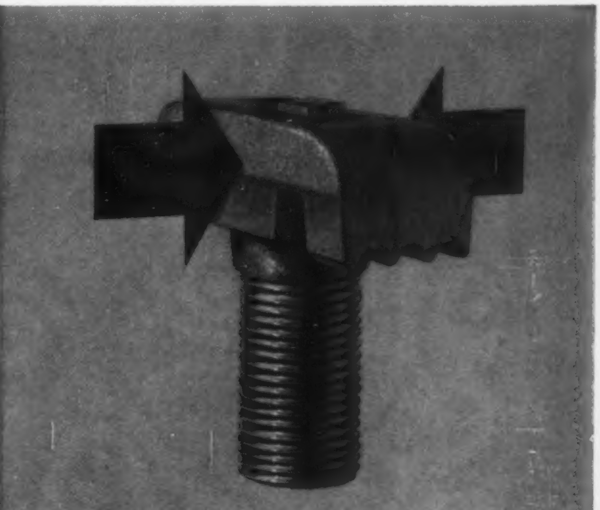
PENNSYLVANIA
Buck Iron Company, Inc., Philadelphia 22
Erie Malleable Iron Co., Erie
Lancaster Malleable Castings Co., Lancaster
Lehigh Foundries Company, Easton
Meadville Malleable Iron Co., Meadville
Pennsylvania Malleable Iron Corp., Lancaster

TEXAS
Texas Foundries, Inc., Lufkin

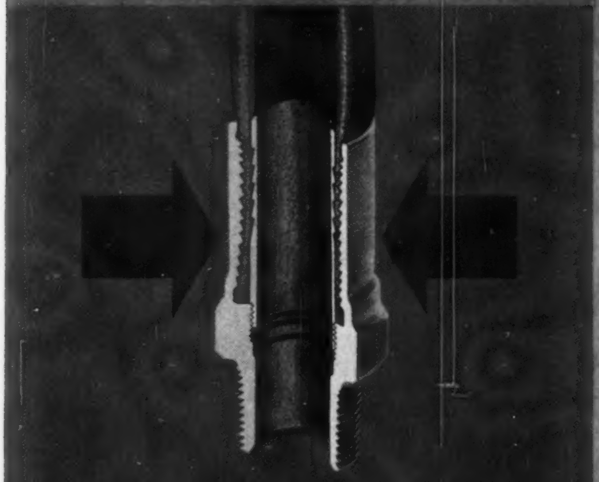
WEST VIRGINIA
West Virginia Mall. Iron Co., Point Pleasant

WISCONSIN
Belle City Malleable Iron Co., Racine
Chain Belt Company, Milwaukee 1
Federal Malleable Company, Inc., West Allis 14
Kirsh Foundry Inc., Beaver Dam
Lakeside Malleable Castings Co., Racine
Milwaukee Malleable & Grey Iron Works, Milwaukee 46

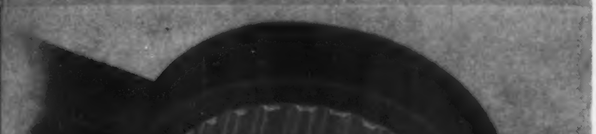
Bend It — A 30% cost reduction was achieved by casting this Malleable iron twine finger flat . . . then bending the arm about 45 degrees and coining the center hub in one fast, post-forming operation.



Coin It — Very close tolerances are often met economically by either cold or hot coining. The head of this T-bolt is coined to meet tolerances of ± .005″ on its .475″ width without any machining.



Swage It — Long, trouble-free service is built into this high-pressure hose coupling by swaging the Malleable fitting around the reinforced hose in a 15-ton press. It's fast, permanent and economical. Working pressure of the hose is 2,000 psi.



Harden It — Surface hardness values in excess of 55 Rockwell C can be achieved with pearlitic Malleable by either flame or induction hardening. Response is excellent, and results are uniform.

Circle 463 on Page 48-B

Personals . . .

Thomas C. Smith – retired as a consultant to the director of Leeds & Northrup Co.'s engineering department after more than 38 years of service with the company.

Edward W. P. Smith – from purchasing analyst to director of purchases of Bendix-Westinghouse Automotive Air Brake Co., Elyria, Ohio.

Orlo I. Lemmer – from metallurgical engineer to manager, metallurgical service, Vanadium-Alloys Steel Co., Latrobe, Pa.

E. Ronald Einarsen – from Einarsen Associates, Woodcliff, N.J., to eastern area manager with headquarters in Westwood, N.J., for the Metals Div. of National Research Corp., Cambridge, Mass.

Gilbert R. Rothschild – from assistant director, metallurgical research, to assistant director, metallurgical development, heading a new division of the central research laboratories of Air Reduction Co. in Murray Hill, N.J.

Harold Etherington – from manager of the Allis-Chalmers Nuclear Power Dept. in Washington, to general manager of the Allis-Chalmers Atomic Energy Div.

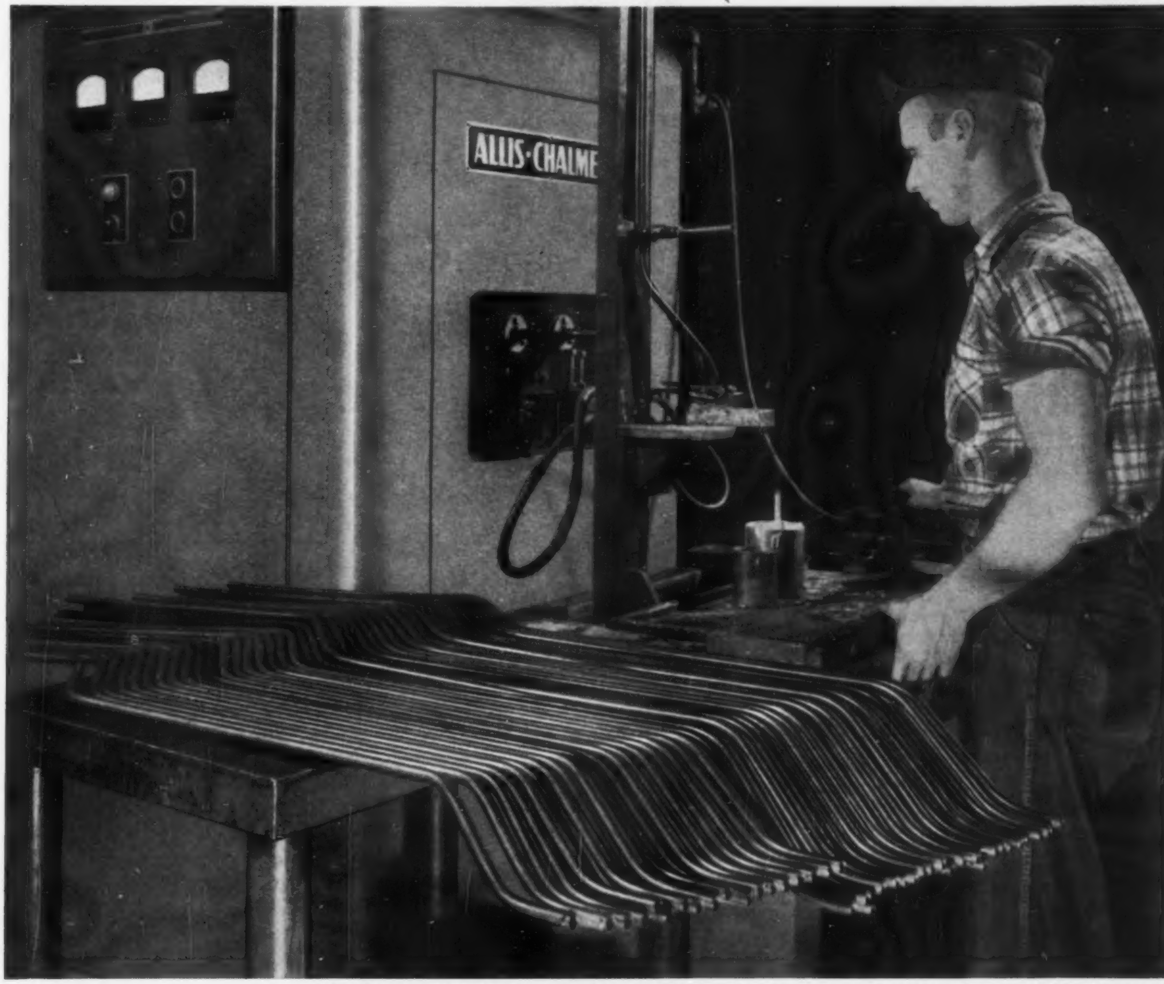
Bruce O. Young – from market development coordinator with the carbon and alloy specialities product division of Crucible Steel Co. of America, Pittsburgh, to manager of the division.

T. B. Winkler – from division head to director of research, processes, at Bethlehem Steel Co., Bethlehem, Pa. At the same time **D. J. Blickwede,** division head, was named director of research, applications, and **J. W. Frame** was promoted from supervisor to associate director, physical metallurgy.

Arun K. Dube – from chemist and wet analyst for Alloys Unlimited Inc., Long Island City, L.I., N.Y., to director of research and engineering, Automation Alloys, Inc., Chicago.

Joseph C. Danec – now head of the metal bond unit of the research and development department, Norton Co., Worcester, Mass.

ALLIS-CHALMERS



Allis-Chalmers induction heater brazing hydraulic tubing to oil pump. Operation is accomplished in seconds.

Allis-Chalmers induction heater replaced torch-brazing setup...

brazed 800% faster

"Both of our Allis-Chalmers induction heaters paid for themselves within 18 months after installation. We are pleased with the quality of work they are doing and they have already become a necessity to us." This is the comment of the production engineer for one of the big three private plane manufacturers . . . a company which now owns several Allis-Chalmers induction heaters. The industry's emphasis on strength without weight makes the induction heater an important production tool.

In addition to the advantages of weight saving on airplane parts, the manufacturer found that production speed on brazing operations could be increased as much as 800% over previous torch-brazing methods and that warpage and rejects were reduced 80%.

Such benefits as speed and economy make Allis-Chalmers induction heaters worth your consideration for soldering, annealing, melting, brazing, hardening, or forging.

Allis-Chalmers excels in larger applications — induction heaters up to 150 kw have been applied to speed up production, save labor and improve product quality. Allis-Chalmers points to a significant number of larger installations.

• • •

Let us talk with you about possible applications. Call your A-C representative. Or write **Allis-Chalmers,** *Industrial Equipment Division, Milwaukee 1, Wisconsin.* A-1304

Circle 465 on Page 48-B

Metals Engineering Digest

. . . Interpretative Reports of World-Wide Developments

Progress in Brazing

A report on several papers on brazing presented at the 42nd Annual Meeting of the American Welding Society, April 1960, New York.

SOME OF THE PROGRESS being made in brazing – new methods, research into old problems, joining refractory metals and ultrahigh-strength steels, techniques for using inert gases – was discussed at the 42nd annual meeting of the American Welding Society held recently in New York.

Described by Roger A. Long (Narmco Research and Development Div., Narmco Industries, Inc., San Diego, Calif.) was work on exothermic brazing, a joining method which puts to work the heat involved when certain metals and oxides are reacted. This technique, akin to the thermit process, can be used in two ways – either to supply heat for melting a braze alloy or to produce the actual bonding agent.

The advantage of the former method is that commercially available brazing alloys can be used provided the metal through which the heat of reaction must penetrate is thin enough so that it does not prevent the braze alloy from melting. One precaution, of course, is that the heat of the reaction should not be so great that it adversely affects the properties of the metal.

Mr. Long explained some experimental work with the boron-vanadium pentoxide system ($10\,B + 3\,V_2O_5 \rightarrow 5\,B_2O_3 + 6\,V$, 0.73 kcal. per g.). This reaction has been used as a heat source for making lap-shear specimens of 50-mil thick 17-7 PH stainless steel. Specimens were brazed with a 92.5% Ag, 7.2% Cu, 0.25% Li alloy having a flow temperature of 1635° F. The reactants were applied as a suspension (in alcohol) that was painted opposite the joint lap on each back surface of the stainless panels. Ignition was accomplished in argon in a furnace at 900 to 950° F. When heat treated to the TH 1050 condition, and tested, these specimens exhibited shear strengths equivalent to those of conventionally brazed samples.

Such experiments demonstrate that sufficient heat can be produced by a small quantity of reactants (only 0.6 g. per sq.in. were applied to the specimens) to melt the braze alloy and thus permit successful brazing. Further work has shown the feasibility of its use in bonding stainless steel honeycomb panels, in brazing inserts to panels and attaching small parts to larger structures. It may also be employed for making field repairs on structural honeycomb panels.

In the second method of exothermic brazing, the products of the reaction serve as the bonding agent. Systems investigated included those which produced a metal and an oxide, a metal and glass, and a metal, glass and oxide. The last combination gives the best results because it comes closest to providing an all-metal bond.

One of the systems being used

Table I – Exothermic Brazing System

Reactants	Inert Ingredients	Wetting Agents	Products
Metals			**Metals**
7.7% Mg	2.3% Ag	3.8% KHF_2	29.5% Ag
3.4 B	3.7 Borax	2.3 Li_2F	28.8 Cu
Oxides	8.7 SiO_2	0.7 KCl	**Nonmetallics (glassy)**
30.2% Ag_2O		0.1 Pluronic	12.4% MgO
			8.4 SiO_2
37.1 CuO			1.1 Na_2O
			13.0 B_2O_3

Circle 466 on Page 48-B

Progress in Brazing . . .

for brazing thin (3 mils) stainless steel honeycomb foil to 7-mil thick skin is given in Table I. Preliminary tests indicate that 90 to 95% of the honeycomb panel is brazed and that flexural strength is about 80% of that of conventionally produced panels. Improvement is expected since the composition of the mixture is not necessarily the best one. In the system given in Table I, the basic reaction involves magnesium and boron which react with the oxides of silver and copper.

Control of composition is more demanding in formulating exothermic mixtures which produce an adhesive because reactions occur in less than 5 sec. The fluidity of the glass formed is adjusted by additions of silica, lithia, alumina and borax so that the glass can be squeezed from the joint. Pressures are applied during the reaction but just how much must be determined for each exothermic mixture. During work at Narmco, pressures of 50 to 200 psi. have been used. Wetting characteristics, adjusted by the amount of halides in the mixture, are particularly important when brazing stainless steels. The halides permit brazing to be done in air rather than in controlled atmospheres.

Like the reactions which are used strictly for their heat-producing ability, those which produce a bonding alloy are applied as a "paint" in an alcohol carrier or as thin wafers made by pressing the components in a die.

Penetration and Erosion

One of the results of research at Armour Research Foundation, Chicago, is the conclusion that penetration of molten brazing alloys into austenite grain boundaries of plain carbon steel is primarily a function of the interfacial energy between the liquid filler and the solid steel. This finding, reported by Nikolajs Bredzs in his talk on grain-boundary penetration and base-metal erosion, provides further insight into a fundamental brazing problem. For example, if the interfacial energy can be increased then penetration will be decreased. This can be achieved, as pointed out by Mr. Bredzs, by adding nickel to a Fe-B brazing alloy (one of a number of simple

Circle 469 on Page 48-B

alloys used in the research) to produce a ternary eutectic which does not penetrate between the grain boundaries.

How much nickel to include depends on the carbon content of the steel because carbon lowers the interfacial energy and thus permits deeper penetration. It was found that penetration is accompanied by diffusion of carbon from the austenite grains to the grain boundaries; the original Fe-B filler then becomes a Fe-B-C alloy which, upon cooling, releases iron from solution at the grain boundaries leaving a low-melting eutectic. The same phenomenon occurs when a copper filler is used. Carbon diffuses to the liquid filler, and a Fe-Cu-C alloy is formed which has a melting point some 100° F. below that of the original copper filler.

Brazing in Argon

It's not always possible – although desirable – to remove flux from a brazed joint and this is one reason why fluxless brazing in a vacuum or in a high-purity reducing or inert gas has become a necessity. When brazing is done in a gas, the purity of the protective atmosphere will determine the results. Speaking on the technique of brazing in argon, J. W. Hill (Linde Co., New York) emphasized that success hinges on using a gas distribution system and production methods which are designed to prevent contamination.

He pointed out that a good distribution system should be capable of delivering gas to the brazing retort with less than 1 ppm. impurities. Gas purifiers are not necessary and, in fact, may be detrimental. When ordinary pipes, valves and fittings are used, there is a significant influx of outside air into the protective gas. Even though the system is pressurized, there can be diffusion of contaminants against a pressure differential. Threaded joints should be avoided; welded or brazed joints are preferred. Both rubber and plastics permit gases to enter the system, but plastics, specifically fluorocarbons, are less permeable. To seal retorts, Mr. Hill suggests a mechanical or welded joint rather than a sand seal.

But delivering a pure gas to the retort is only half the problem. It is also necessary to remove all possible contaminants from the retort before brazing. This entails more than just displacement of the air inside the retort because, as the temperature is raised, adsorbed gas is evolved, residual cleaning compounds vaporize and binders and hydrates in refractories decompose. Oxygen and nitrogen removal has not proved to be as great a problem as has removal of water. Getting the water content down to a safe level is difficult even at high temperatures and long times. Mr. Hill explained that it is advisable to eliminate refractory fixtures. This may eliminate the need for purging the retort with argon at room temperature and permit the retort to be heated as soon as purging begins. Holding the retort below 600° F. until the water is removed is also recommended. These practices achieve a safe brazing atmosphere in a minimum of time. R.G.D.

Circle 471 on Page 48-B

Circle 473 on Page 48-B

Corrosion of Stainless Steels

Digest of "Comparative Data on the Corrosion Resistance of Selected Types of 18-8 Chromium-Nickel Stainless Steels", by K. L. Sanborn, U.S. Atomic Energy Commission Report No. HW-32727.

To provide comparative data on corrosion resistance, a test program was conducted on four types of stainless steels (Type 347, 347 CbTa, 304 L and 321). Each of these types of 18-8 chromium-nickel steel was compared by three tests commonly used in the chemical industry as quality or acceptance tests, as well as by corrosion tests in six simulated separations process streams. Each material was tested in each of four conditions defined by different thermal histories: as-received, sensitized, as-welded, and welded-stress relieved (at 1600° F.). Unfortunately, because of the scope of the test program, it was not practical to test more than one heat of each material.

The industrial acceptance tests were the Huey test, Strauss test and the nitric acid-hydrofluoric acid test. The simulated separations process streams were four $BiPO_4$ solutions and two TBP process solutions. Duplicate tests were made in each of the heat treated conditions (all heat treating being done in electrically heated furnaces which were open to the atmosphere). After treatment, the specimens were pickled and passivated, rinsed in both water and methanol, air dried, and weighed. A fresh solution was used for each exposure period, and all specimens were cleaned with soap, water and a bristle brush before checking the weight loss. In addition, weight loss data was supplemented by microscopic and macroscopic examinations. Specimens exposed in the Strauss test were also subjected to a bend test, and the surfaces examined for cracks.

Types 347, 347 CbTa and 304 L were acceptable as evaluated by the Huey test, and were nearly identical in all conditions of heat treatment studied – with the exception of the welded-stress relieved condition. In the latter, corrosion rates were not reproducible and were not considered accurate; with each alloy tested there was considerable attack on the weld deposit. Intergranular attack was light in all cases, and was not considered grounds for rejection. Type 321 suffered higher corrosion rates than any of the other types, exceeding 0.0020 in. per month (the normal limit of immunity) in two of the four conditions and barely meeting it in the other two.

All four of the steels passed the Strauss test, which in the light of the experience gained in this test program was judged to be a less discriminating test than the Huey test. On the other hand, the nitric acid-hydrofluoric acid test was too severe to give reproducible results with routine control. Type 347 and 304 L suffered higher corrosion rates in this test than Types 347 CbTa and 321, but data from other sources failed to substantiate that the presence of titanium or tantalum might be responsible for a real improvement in the corrosion resistance of 18-8 stainless steels in this solution.

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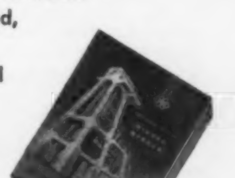

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Circle 475 on Page 48-B

Stainless Steels . . .

Types 347 and 321 showed evidence of less severe intergranular attack than either type 347 CbTa or 304 L.

Corrosion rates of 0.0005 in. per month or less were observed for each of the alloy types in all the simulated separations process streams with the exception of one which contained about 1% hydrofluoric acid. In this, corrosion rates up to 0.0031 in. per month were found.

In general, there was a higher incidence rate for intergranular attack on specimens of Type 347 CbTa than for the other types tested. The severity of the attack was not great, however, and should be considered a critical factor only in specific mediums, such as nitric acid-hydrofluoric acid solutions which are known to promote severe intergranular attack.

The data found in this test program led to the conclusion that of the three common acceptance tests employed the Huey test is the most reliable despite the controversy on its usefulness, and it should be used in the procurement of stainless steels for all but specifically excepted separations services.

C. W. McKee

Cobalt and Corrosion Resistance

Digest of "The Corrosion Resistance of Some Stainless Steels Alloyed With Cobalt", by D. Coutsouradis, *Cobalt*, No. 5, December 1959, p. 3-14.

This report describes some corrosion work concerning the influence of cobalt additions on the mechanical and chemical properties of ferritic and austenitic stainless steels. Included are corrosion of 17 and 27% Cr alloys caused by immersion in 10% sulphuric acid at room temperature, by boiling in 65% nitric acid (Huey test) and by boiling in sulphuric acid-copper sulphate solution (Strauss test). Polarization curves were determined for some of the alloys.

Alloys of commercial purity were induction melted, forged, prepared into specimens which were then heat treated and corrosion tested. These alloys contained <0.012 S and <0.033 P, and had the following composition:

Steel	Cr	Co	Ni	Ti
1	17.9	–	2.07	–
2	17.5	2.05	2.01	–
3	17.9	–	–	–
4	17.9	1.56	–	–
5	18.4	6.10	–	–
6	18.2	–	–	0.48
7	18.1	2.94	–	0.51
8	26.8	–	–	–
9	27.5	1.52	–	–
10	27.6	5.9	–	–
11	16.9	–	9.4	–
12	17.1	5.1	9.4	–
13	16.9	10.1	9.5	–

Judging from the total immersion tests in aerated sulphuric acid, additions of cobalt decreased corrosion rates for all steels. Figure 1 illustrates the effect of cobalt content on the corrosion of a heat treated 18% Cr steel.

The ferritic stainless steels (Steels 1 through 10) were heat treated and tested for susceptibility to intergranular corrosion. Alloys 1, 2, 3, 4 and 5 displayed an increase in corrosion resistance to nitric acid (Huey test) with increasing cobalt content and with increasing quenching temperature from 475 to 1200° C. (880 to 2190° F.). When the tempering time at 475 and 500° C. (880 and 930° F.) was increased from 30 min. and 1 hr. to 100 and 1000 hr., a substantial increase in corrosion rates with cobalt content was noted. The titanium-containing alloys, 6 and 7, exhibited increasing corrosion rates with increasing quenching temperature in the 800 to 1200° C.

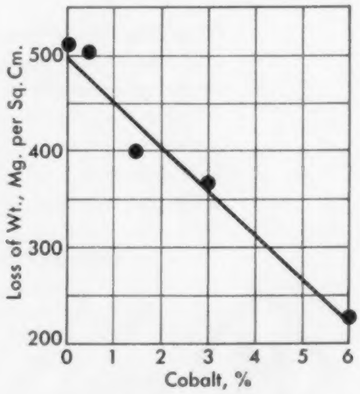


Fig. 1 – Cobalt Additions Increase Corrosion Resistance of 18% Cr Steels. Specimens were austenitized, oil quenched, tempered at 500° C. (930° F.), and immersed in 10% H_2SO_4 for 70 hr.

(1470 to 2190° F.) range. Of the two, alloy 7, which also contained cobalt, displayed the better resistance. Long-time heat treatments at 475 and 500° C. (880 and 930° F.) resulted in low corrosion rates.

Like the rest of the steels, the 27% Cr alloys displayed increasing corrosion resistance with increasing cobalt content. Strauss tests revealed better results for the cobalt containing alloys. The austenitic alloys 11, 12 and 13, quenched from 1100° C. (2010° F.) with and without a subsequent heat treatment at 600° C. (1110° F.), were examined, and cobalt had little effect, according to the Huey test.

Polarization curves were obtained by intensiostatic (constant current) and potentiostatic methods. Although both methods measure the current densities at which passivation occurs, the latter method permits a more exact determination because of the instability of potential in the passive region. Curves obtained by both methods for a series of 18 and 27% Cr alloys were in good agreement.

Cobalt in the alloys results in a decrease in the maximum current attained for the metals in the active conditions. For example, 6% Co added to the 18% Cr alloy reduced the current density from 4 to 1 milliamp. per sq.cm. A similar decrease was observed for the 27% Cr series of alloys. At higher potentials, corresponding to dissolving of the alloy elements in their maximum oxidation state for the 27% Cr alloy or the evolution of hydrogen with some dissolution of alloy elements for the 18% Cr alloy, very little effect was noted with the cobalt additions. Also, cobalt additions did not affect the polarization of the austenitic stainless steels employed.

F. H. Beck

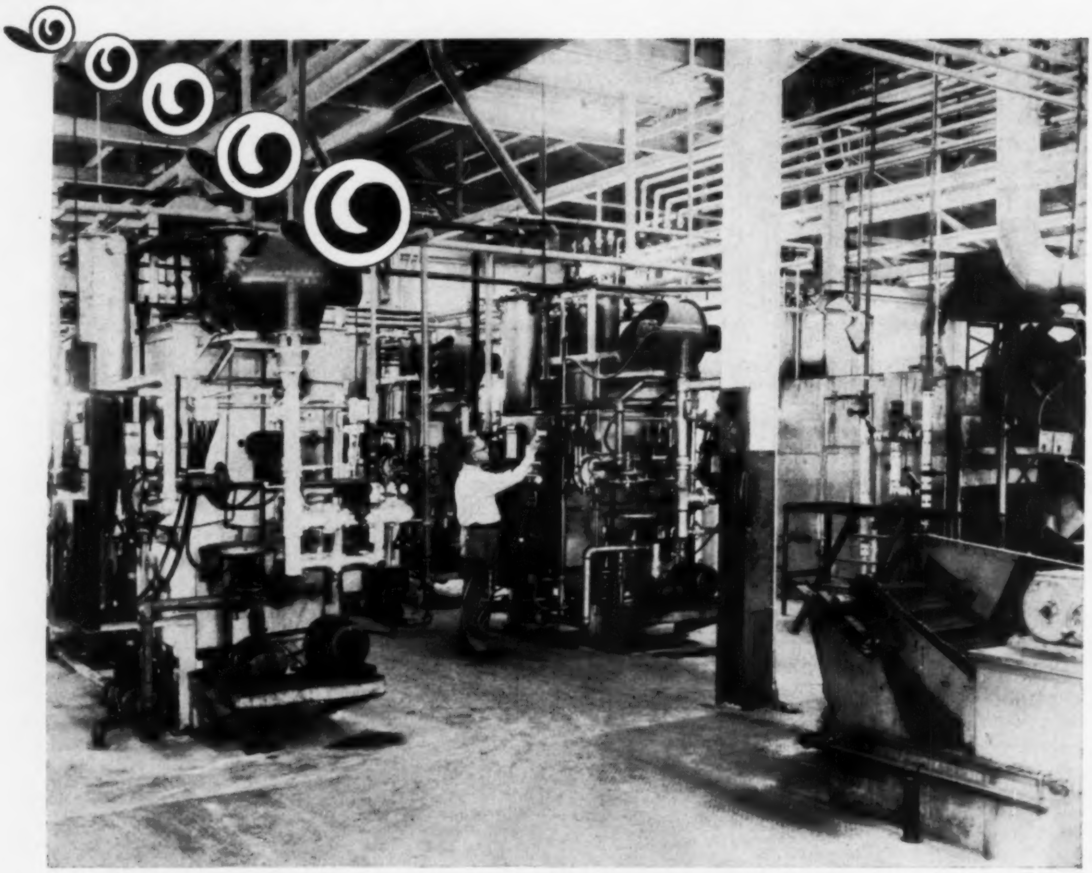
Flame-Sprayed Coatings

Digest of "Flame-Sprayed Coatings", by Frantisek Princ, *Czechoslovak Heavy Industry*, No. 7, 1959, p. 28-35.

Flame spraying may be defined as the atomization of a substance and the subsequent deposition of its molten particles on the surface of a previously prepared machine part. Upon solidification, the drops

(Continued on p. 158)

Here, Precision's in the Air



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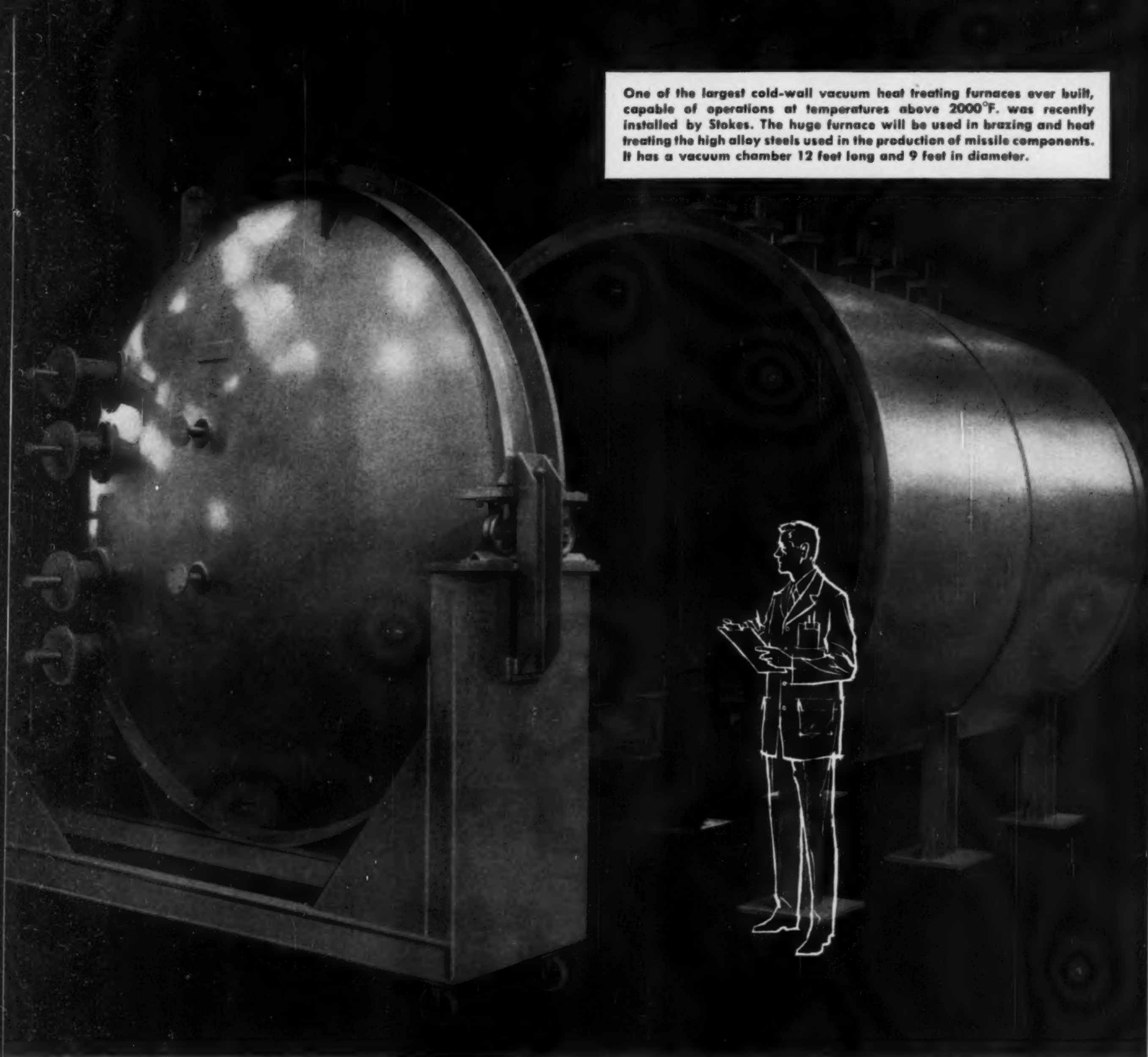
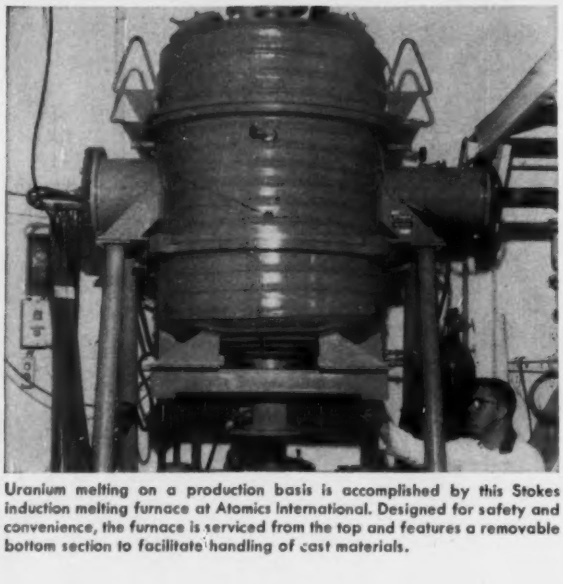


One of the largest cold-wall vacuum heat treating furnaces ever built, capable of operations at temperatures above 2000°F. was recently installed by Stokes. The huge furnace will be used in brazing and heat treating the high alloy steels used in the production of missile components. It has a vacuum chamber 12 feet long and 9 feet in diameter.



Uranium melting on a production basis is accomplished by this Stokes induction melting furnace at Atomics International. Designed for safety and convenience, the furnace is serviced from the top and features a removable bottom section to facilitate handling of cast materials.

First acid open hearth, vacuum stream ladle degassed, air-pouring of multiple ingots in the U. S. took place at Ohio Steel Foundry in Stokes equipment. Results showed low hydrogen values, good inclusion reduction and excellent physical property improvement.

Circle 483 on Page 48-B

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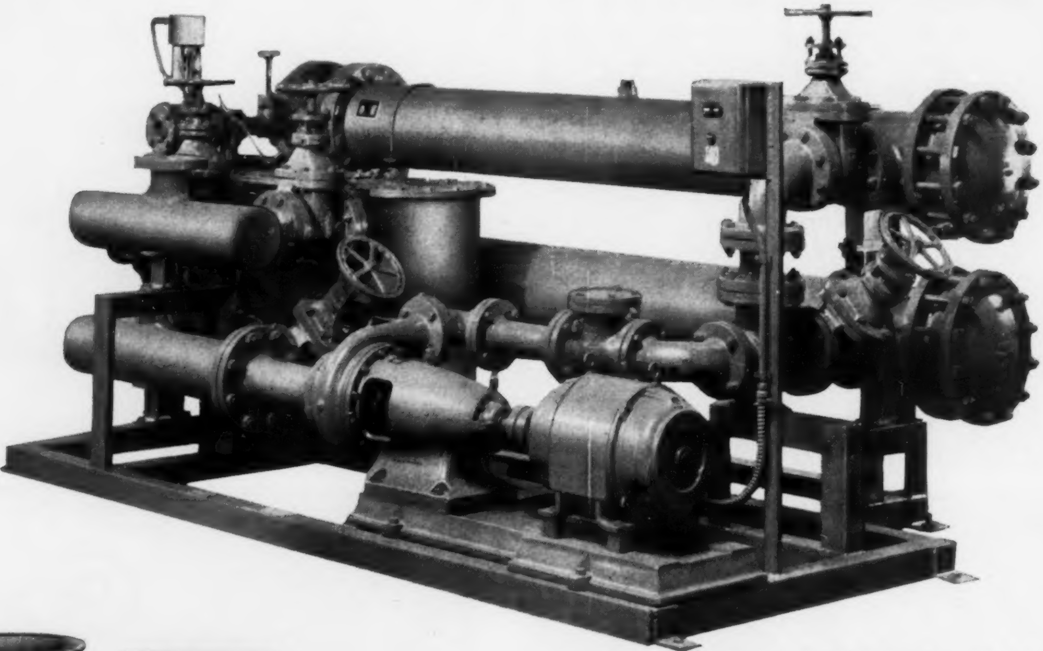

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Circle 484 on Page 48-B

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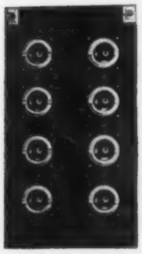

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Circle 485 on Page 48-B

Coatings . . .

of molten material form a porous coating whose mechanical and chemical properties differ greatly from those of the original material. At present, commercial applications are limited almost entirely to the spraying of metals (metalization), but processes are being developed for spraying oxides, carbides, glasses, enamels and other inorganic substances. The process is used extensively for rebuilding and repairing worn parts, applying scale and corrosion-resistant coatings to metal surfaces, repairing porous, mismachined and defective castings, repairing bearings and the like.

Though metalizing is relatively simple, careful control must be exercised throughout the process to insure that the coating will adhere to the base metal. The process may be divided into three steps: preparation of the base-metal surface, the spraying itself, and the supplementary coating surface treatment.

Since the bond between the base metal and the sprayed coating is purely mechanical, the base metal must have a clean rough surface to increase the adhesive power of the sprayed particles. This type of surface may be obtained by grit blasting with clean grit, by rough machining, hammering, electrodic roughening, or any similar operation.

The spraying operation must be performed shortly after the roughening operation to prevent oxide formation which would reduce the adhesive power of the sprayed particles. In addition, the angle at which the spray impinges on the surface of the base material must be between 45 and 90°, the distance between the spray gun and the workpiece must remain constant, and the surface of the workpiece must not get hotter than 200° C. (390° F.) during metalizing.

As a final precaution, when spraying cylindrical parts with a diameter greater than 10 cm. (4 in.), trapping shields must be used to eliminate particles which would impinge on the surface at an undesired angle.

The sprayed coatings may be mechanically treated (such as machining or grinding), chemically treated or sealed (such as by a passivating

(Continued on p. 164)

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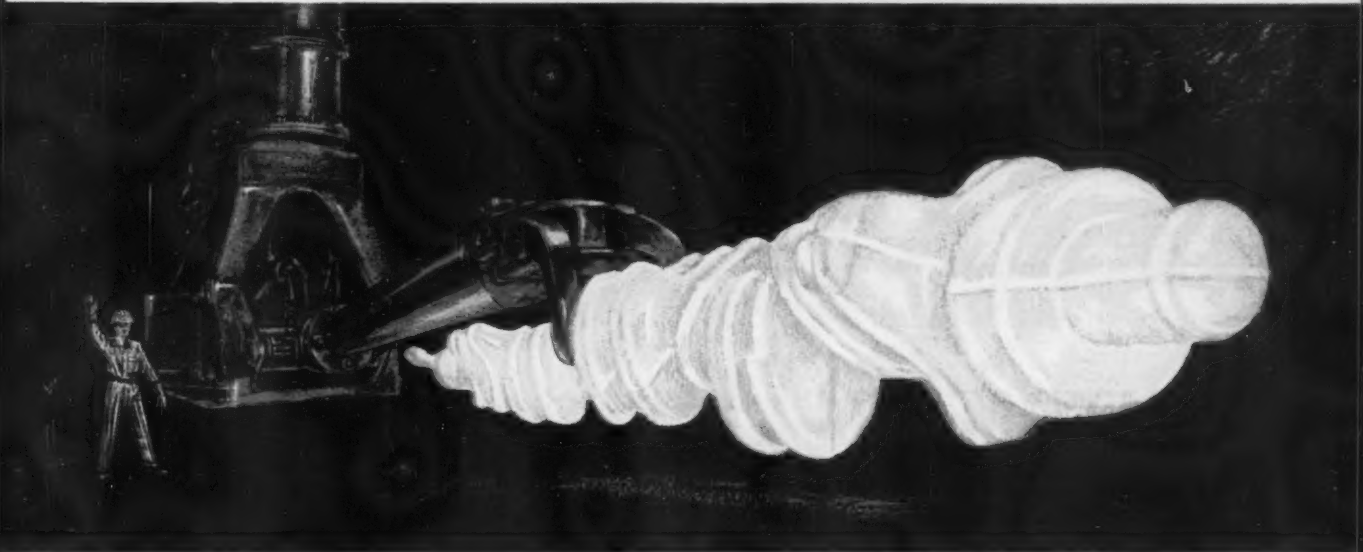

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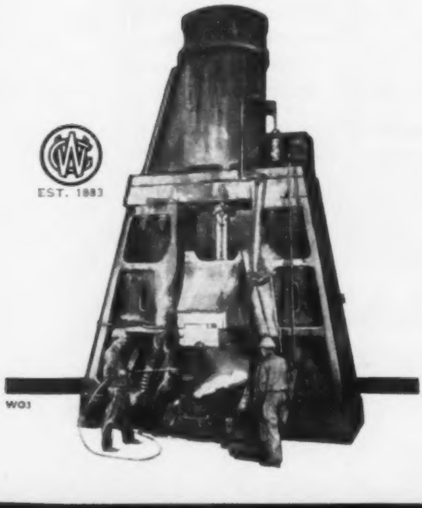
Circle 407 on Page 48-B



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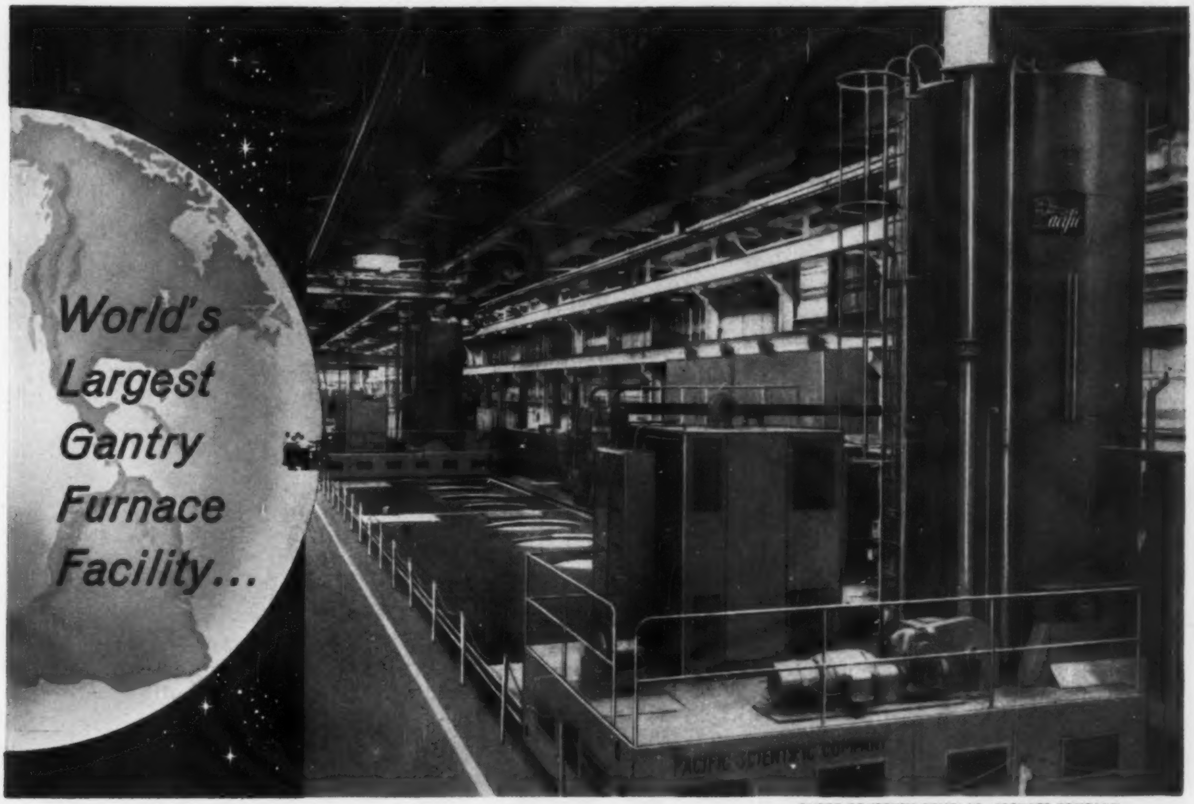
Circle 488 on Page 48-B



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Circle 490 on Page 48-B

Circle 491 on Page 48-B

Coatings . . .

treatment or impregnation of the surface), or thermally treated (such as heating of aluminized surfaces to increase their resistance to scaling). The use of any of these treatments is determined by the function of the sprayed component. For example, the surface of a rotating shaft would have to be machined or ground, but a heat-resistant coating might be subjected to a thermal treatment.

Three types of guns may be used for flame spraying. They differ in accordance with the material used for spraying (molten metal, metal powder or metal wire) but they function in essentially the same manner. At present, the wire gun is the one most widely used.

As for advantages, there is no deformation (the part is not heated); coating thickness may be varied at will, and the coating may be machined by turning or grinding. Finally, any metal may be applied to any other metal with no consideration of the chemistry or microstructure of the base material since the bond is mechanical.

BERNARD TROCK

Magnetite in Steel Scales

Digest of "A Magnetite Seam at the Scale-Metal Interface on Mild Steel", by K. Sachs and G. T. F. Jay, *Journal* of the Iron and Steel Institute, June 1960, p. 180-188.

THIN LAYERS of magnetite are sometimes observed between the scale and the metal when adherent scales are formed on hot rolled mild steel. This is a deviation from the classical three-layer structure — three layers from iron out are wüstite. magnetite and ferric oxide in that order — normally associated with adherent scales. The magnetite layer is believed to result from oxygen penetration under the scale or from localized nucleation of the breakdown of wüstite.

In the first instance, the authors suggest that magnetite may form as a border to a gap containing oxygen. A healing process then re-establishes contact with the metal surface. Explaining the persistence of the magnetite seam is difficult on the basis of this mechanism. Therefore, the

(Continued on p. 170)

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The bath doesn't go acid, even with metal chips in it. That's because the stabilizer has *psp*—permanent staying power. In more than five years of degreasing with Nialk TRICHLOR, McCord has never had to titrate or make any similar test.

"I don't see how you could find anything more appropriate to our type of operation," says Frank McDonald, plant foreman. "Nialk TRICHLOR is fast and efficient."

Ray B. Preston (left) of the P. B. & S. Chemical Company, the local Nialk TRICHLORethylene distributor, and McCord Corporation's plant manager, John C. Padden, discuss critical cleaning requirements.

Besides being pleased with the large volume of material degreased between cleanouts, Mr. McDonald has found "the help of the Hooker people in the operation of our degreaser of great benefit to us."

Whatever your metal, whatever your degreasing job, you can solve your cleaning problem with Nialk TRICHLOR. See your chemical distributor or drop us a line. Hooker experience is yours for the asking.

HOOKER CHEMICAL CORPORATION

407 UNION STREET, NIAGARA FALLS, NEW YORK

HOOKER CHEMICALS PLASTICS

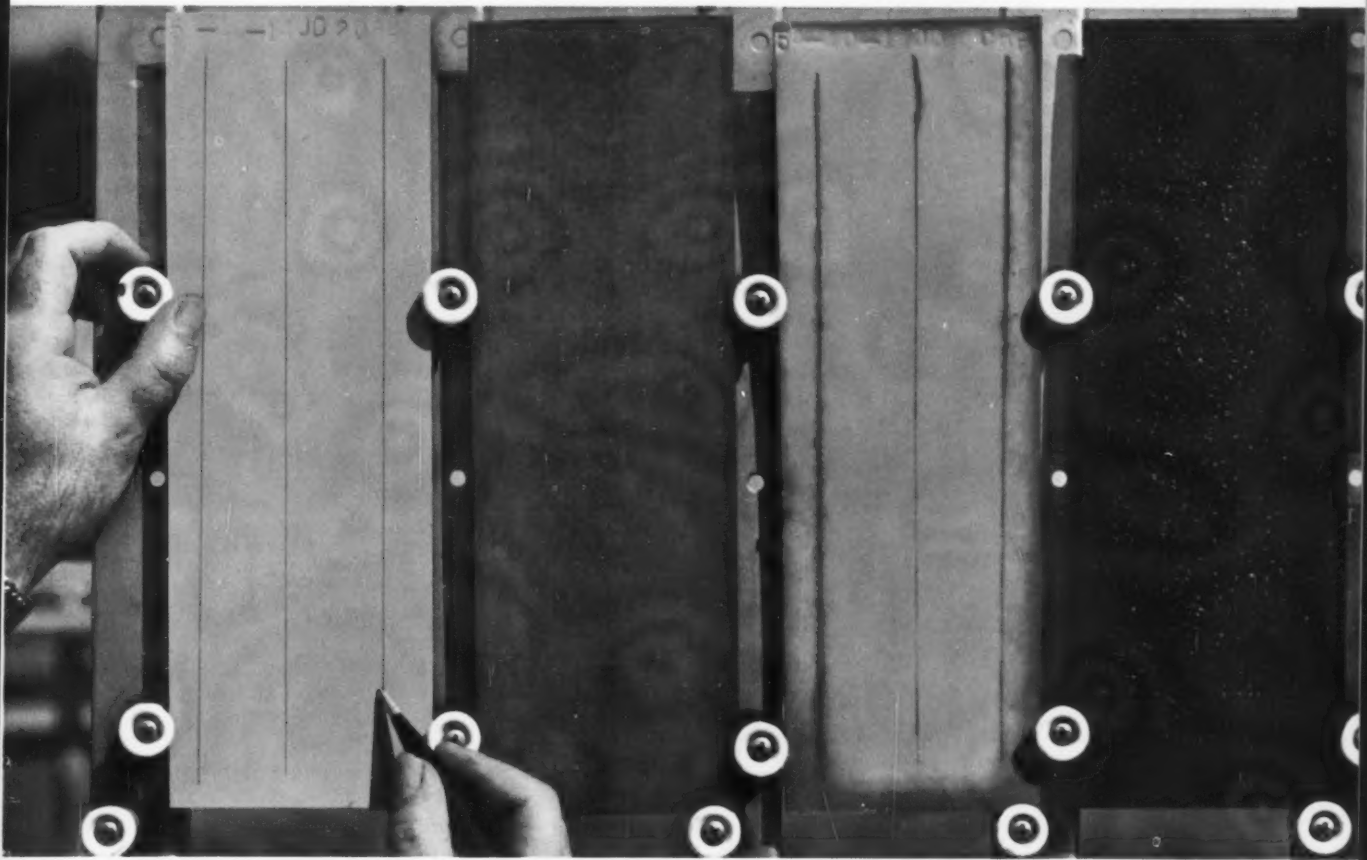
Sales offices: Buffalo, Chicago, Detroit, Los Angeles, New York, Niagara Falls, Philadelphia, Tacoma, Worcester, Mass. *In Canada:* Hooker Chemicals Limited, North Vancouver, B.C.

Circle 493 on Page 48-B

New steels are born at Armco

ZINCGRIP A, PAINTGRIP

1 2 3 4

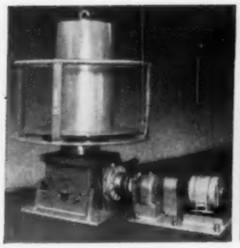
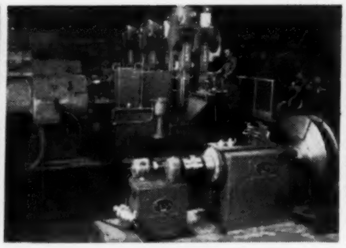
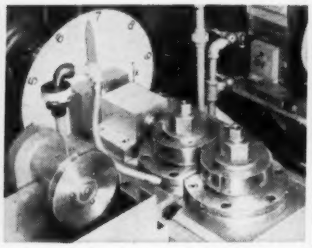
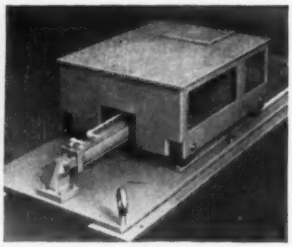


This half-painted bus body fabricated from Armco ZINCGRIP A, PAINTGRIP has been exposed for 2½ years. Paint finish is still smooth and attractive, the unpainted surface rust-free.

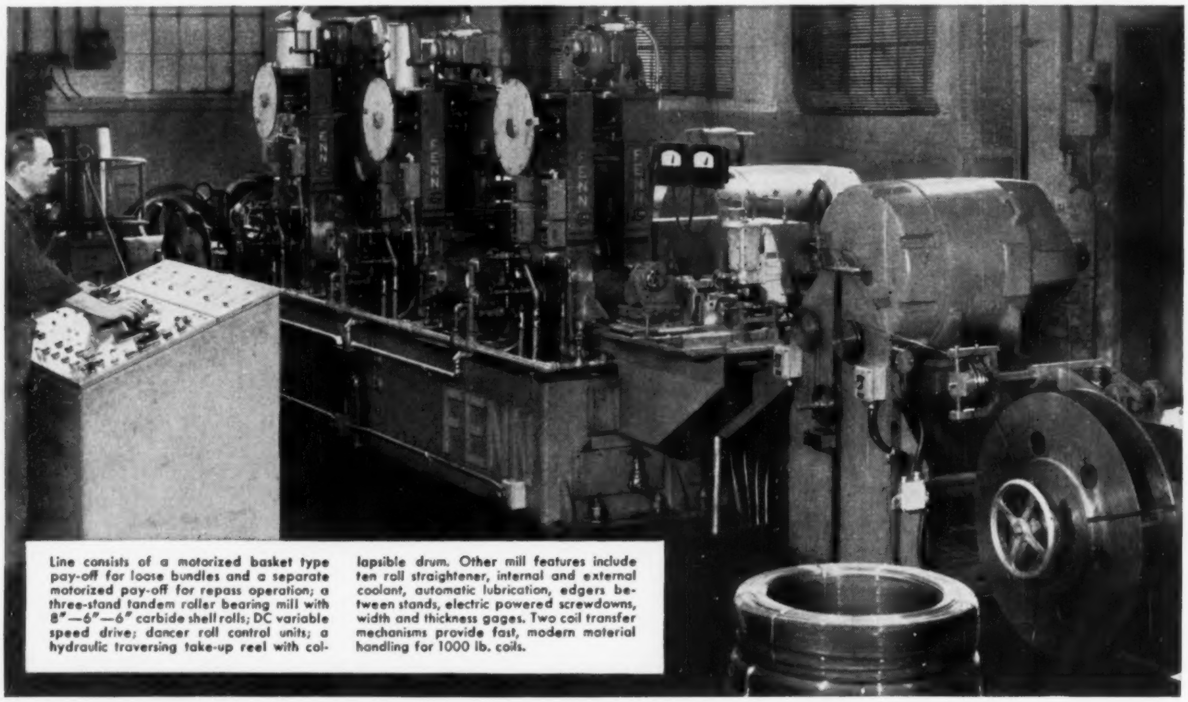
After 3-years' exposure outdoors, paint holds tightly to sample of Armco ZINCGRIP A, PAINTGRIP (1), even where scratched at start of test. Where unpainted (2) there's no rust either. In contrast, painted and unpainted phosphate-treated cold-rolled steel panels (3 and 4) are in poor condition. Paint has been undercut. Rust is entrenched.

Galvanized Steel

Use this label to point out durable zinc-coated steels in your products

PRODUCING SPRING STEEL FLATS AT 3100 FPM



Line consists of a motorized basket type pay-off for loose bundles and a separate motorized pay-off for repass operation; a three-stand tandem roller bearing mill with 8"—6"—6" carbide shell rolls; DC variable speed drive; dancer roll control units; a hydraulic traversing take-up reel with collapsible drum. Other mill features include ten roll straightener, internal and external coolant, automatic lubrication, edgers between stands, electric powered screwdowns, width and thickness gages. Two coil transfer mechanisms provide fast, modern material handling for 1000 lb. coils.

pace-setting precision wire flattening mill

This three-stand tandem mill represents the finest in high speed precision wire flattening equipment. Installed at one of the nation's largest producers of spring steel, it offers significant advantages in flexibility, customer service, and finer stock finish. Production is greatly simplified with special material handling accessories, and the ability to produce flats from starting rounds entirely eliminates the customary slitting operation. Perhaps, like this progressive manufacturer, the time is at hand to evaluate your wire flattening equipment in terms of the economic justification for modernizing to the standards set by Fenn mills. Fenn's long experience is at your service. Fenn engineers will study your specific requirements and make recommendations for equipment to your competitive needs. The Fenn Manufacturing Company, Fenn Road, Newington, Connecticut.

Designed and Built by **FENN**

Circle 494 on Page 48-B

Magnetite . . .

authors suggest the formation of magnetite in the absence of local oxygen enrichment to be more likely. This would mean that wüstite decomposition would have to take place below 480° C. (900° F.) and precipitate magnetite at the wüstite-metal interface. On the basis of the composition of the wüstite, this is unlikely since wüstite saturated with oxygen is more readily transformed. Wüstite decomposition would therefore be expected to start at the outside of the wüstite layer.

The above unfavorable concentration effects of both oxygen and iron for wüstite decomposition at the oxide-metal interface may be offset by enrichment of elements other than iron at the interface. These other elements may then lower the stability of the wüstite, permitting magnetite to form. The authors report experimental evidence indicating the presence of nuclei for deposition of a magnetite seam, and consider the following three possible mechanisms for the nucleation of wüstite decomposition at the metal interface:

1. Residual magnetite from a gap that has been healed may nucleate the decomposition of wüstite into magnetite and iron-rich wüstite.

2. Compressive stress in the wüstite at the metal-oxide interface may favor the initiation of wüstite decomposition. Contraction resulting from precipitation of magnetite acts to relieve compressive stresses. The high internal stresses at the interface would favor the precipitation of magnetite. This contraction associated with the growth of magnetite at the interface could explain the formation of cavities which are often observed.

3. Nucleation based on the suggestion that an adherent scale layer prevents escape of CO and CO_2 from the metal surface which, in turn, supresses decarburization. In this instance, equilibrium must exist for the activity of carbon in solution in the steel and in the scale; and also, some solubility of carbon in wüstite must exist. If the stability of wüstite is decreased by the presence of carbon, which would be highest at the scale-metal interface, magnetite could be formed.

F. H. Beck

Toughness in Weld Metal

Digest of "Factors Which Affect Low-Alloy Weld Metal Notch Toughness", by Stanley S. Sagan and Hallock C. Campbell, Welding Research Council Bulletin No. 59, April 1960, 16 p.

This comprehensive report on a large number of tests relates the effect of metallic arc welding variables on the Charpy V-notch toughness of the deposited weld metal. The following factors are evaluated in terms of the Charpy test:

1. Weld metal analysis and the effect of alloying elements.

2. Charpy V-notch values from −80 to +75° F.

3. Electrode size

4. Effect of heat treatment, including preheat and stress relief.

5. Welding position, free and restrained.

6. Dilution of weld metal by base metal.

Test specimens were prepared from 18-in. long plates conforming otherwise to the requirements of the MIL-E-19322 specification for tensile test plates. From each plate, the researchers obtained two tensile test specimens and 15 to 20 Charpy specimens, each specimen being cut at right angles to the weld. Charpy V-notches were centered in the longitudinal center axis of the deposited weld metal.

Good test results were obtained with low-hydrogen E 70 XX electrodes even though many previously reported Charpy V-notch data for closely similar tests indicated otherwise. Higher strength electrodes, conforming to AWS E9018-D1 classification, similarly showed improvement over previously reported Charpy V-notch values. As electrode size increased, however, Charpy values dropped. (In the paper various factors concerned with this trend are presented in some detail.) Charpy values generally rose in weld metal specimens om electrodes with higher lime or more iron powder (or both) incorporated in the coating.

A discussion is presented on the influence of alloying elements. Though manganese, nickel, and molybdenum improve Charpy values at low temperature, these values are still too low to recommend these alloys for low-temperature service.

The authors present an excellent summary of the relationship between stress-relief variables and Charpy values. A difference of 50° F. in the stress-relief temperature will, in many instances, show appreciable differences in Charpy values for otherwise identical test specimens.

Weld metal which responds to secondary hardening (or perhaps precipitation hardening) will, after stress relief, embrittle although the tensile strength will quite likely increase. Where tensile strength is lowered by stress relief, Charpy V-notch toughness will increase.

Preheat improves Charpy values only for certain mild steel electrodes and for low-alloy electrode deposits, which are also low in tensile strength. The effectiveness of preheat decreases with increasing alloy content and higher tensile strengths. It is the opinion of the reviewer, however, that this factor is of secondary importance since most of the high-alloy or high tensile strength materials require preheat for satisfactory welds. Also, the reviewer feels that suitable welding procedures can be predetermined by an accurate knowledge of the metallurgical behavior of the metal welded and the electrode.

Data presented indicate a lowering of notch toughness as the weld position changes from the flat through horizontal or overhead, and vertical. Such would be expected since these variations in weld positions involve very appreciable changes in the welding procedures.

The authors close with an accurate summation that reflects the relationship of Charpy V-notch toughness to

Weld Metal . . .

the welding variables as follows:

1. Use electrodes 3/16 in. or smaller in diameter.
2. Weld preferably in the flat position and avoid welding in the vertical position.
3. Use moderate preheat.
4. Use the type of welding current for which the electrodes are primarily designed.
5. Control and, in high strength steels, avoid dilution.
6. Reinforce weldments in lighter-gage material.
7. Stress relieve mild steel weldments.
8. Avoid stress relieving weldments exceeding about 90,000 psi. tensile strength; if stress relief is compulsory, heat treat at temperatures close to the lower critical transformation point of the base material.

W. T. TIFFIN

Phosphate Coatings

Digest of "On the Properties and Structure of Phosphate Coatings", by V. Cupr, *Metallo-berflache*, Vol. 14, No. 1, 1960, p. B1-B2.

THE CHEMICAL COMPOSITION, crystal structure and thermal stability of phosphate coatings on steel have been investigated. For the work, steel specimens were coated at 95° C. (200° F.) with a composition consisting of zinc phosphate accelerated with nitric acid. After rinsing in warm and cold water, these samples were dried at 30° C. (85° F.) for 6 hr. or at 115° C. (140° F.) for 10 min. Next, the brown coatings were removed (by bending the specimens repeatedly) for chemical analyses, x-ray diffraction, gravimetric and thermal differential analyses.

Coatings were found to be zinc phosphate tetrahydrate, $Zn_3(PO_4)_2 \cdot 4\,H_2O$, with a definite crystalline structure. The compound thermally decomposes to the trihydrate above 210° C. (410° F.) and to the dihydrate above 320° C. (600° F.). At 400° C. (750° F.), the compound changes to the anhydrous form, with an alpha-hopeite structure. Near 850° C. (1560° F.), it becomes a glass-like mass, but does not change composition.

Each of these reactions is strongly time-dependent and endothermic in nature. Thus, for short times even up to 1000° C. (1830° F.) coated steels can be formed without materially altering phosphate composition.

Up to 9% Fe was found in phosphate specimens; x-ray studies showed this iron to be isomorphously integral with zinc ions in the phosphate compound. The iron content in the coating correlates with iron concentration in the phosphate solutions used to coat specimens, and appears to contribute to a less stable coating on steel. Aging gives rise to mixtures of tetrahydrate and dihydrate, the proportion of dihydrate increasing with time. It is concluded that the iron ions strongly influence the manner in which hydration water is bound to the phosphate molecule.

The results of this study suggest that phosphate coating solutions should be changed frequently to minimize contamination of the coating from iron.

J. L. WYATT

Trends in Metal Removal

Digest of "Future Trends in Materials Removal Techniques", by M. Eugene Merchant. Preprint T40 of paper presented at the S.A.E. National Aeronautic Meeting, April 1960, New York.

THOUGH THE FUTURE TREND in the improvement of metal removal processes is difficult to predict, it is sometimes possible to extrapolate past trends. The problem is, then, to examine tomorrow's needs for metal removal machines and to determine what qualitative trends are associated with them. These have been summarized as: *(a)* improved versatility through automatic control, *(b)* improved precision through the ability to achieve closer tolerances, and *(c)* improved productivity in the face of rising strength levels in the work material.

Automation of machine tools began with power feed in 1820, continued with automatic tracing in 1955, automatic programing in 1955, and automatic tooling in 1959. While manpower requirements have moved steadily downward, it is interesting to note that the trend appears to be exponential with time. A plot of this would suggest that the man-hour requirements have been cut approximately in half every ten years. Thus, by the year 1970 we might expect that the relative manpower requirements would be reduced to about one half of what they are today. One of the factors already beginning to appear is "automatic design".

The second qualitative trend, closer tolerances, has had a similar behavior over the years. Wilkinson's boring machine broke the first barrier in 1775. With the invention of the micrometer in 1900, further improvements were possible. Since that time, machine tools have been able to machine whatever accuracy could be measured. The improvement again appears to be exponential with time, and a plot would indicate an increased rate beginning about 1900. A strong physical limitation does lie ahead, namely the size of the atom. Machining accuracy can hardly exceed this accuracy, about one-hundred-millionth of an inch.

The third qualitative trend, the need for improved productivity with metals of increased strength levels, shifts attention from the machine to the metal removal process. The strength of airframe materials, for example, has shown a fourfold increase since 1920, while the permissible cutting speeds have decreased only by a factor of two. Research on metal cutting operations has, however, permitted increased cutting speeds as compared to the speeds used when the new alloys were first introduced. By extrapolation, it appears that even with continued metal cutting research, the permissible cutting speeds will decrease unless these research programs are strengthened and widened to include new objectives and new approaches.

One of the big factors in the past bettering of the machining process was the improvement in cutting tools. Stronger tool steels have allowed increased cutting speeds, or an increase in the permissible strength level of the alloy being cut. However, it now appears that brittleness of the tool material will be a limiting factor; further research must be concentrated on this aspect of tool steels.

Changes in geometry can also improve cutting tools. The introduction of negative rake was a major advance, and further improvements are now in the laboratory stage. The alloy can also be modified to improve the metal removal process. Hot machining, where the work material is heated locally just ahead of the cutter has already permitted the tripling of the cutting speed while cutting high-strength steel. Consideration might be given to other means of modifying the properties of the work material.

Unconventional cutting conditions may also be explored. Cutting at speeds near 100,000 ft. per min. is now being tried as a means for increasing productivity. A number of unconventional metal removing methods must also be examined, such as chemical and electrical removal. While there is no well-defined trend that can be used to predict their future, significant improvement has been made. Still further in the future are the possibilities of applying plasma jets, electron beams, and high-velocity fluids to cut metals.

R. F. HARTMANN

BEHIND THE BYLINES

The process for direct nitriding of stainless steel parts described by Vincent J. Coppola on p. 83 was developed while he was assistant chief metallurgist of the commercial product division at Cameron Iron Works in Houston, Tex. Since last July, he has been manager of Metallurgical Consultants, a consulting firm he opened in Houston. A 1943 graduate of the University of Alabama with a B.S. degree in chemistry, metallurgy and ceramics, he served in the Navy for three years, then joined the National Bureau of Standards as a metallurgist. In 1949 he turned to teaching, becoming instructor in physical metallurgy at Iowa State College. After

a short tenure with Kearney and Trecker Corp., he joined Boeing Airplane Co., Wichita, Kan., in 1951 as quality control engineer in charge of the metallurgical section of the quality control department, then in 1957 moved on to Solar Aircraft Co.

Asked about his other interests or hobbies, Vince says that "with four women in the family, I am happy to state that I simply don't have time for hobbies". He's shown in the photo above with Marie (9), Eldrid his wife, holding the newest family member, Anne (6 months), and Jane (6).

Douglas Aircraft's work on motor cases for missiles resulted in the three-article series (beginning on p. 97) which covers improved design, more accurate tests and fabrication methods. John H. Cunningham, author of the first article on improved design is responsible for structural design analysis methods at Douglas, including work on Nike-Zeus missiles and Polaris motor cases. Now group engineer, structures research and development in the missiles engineering structures section, he came to Douglas in Santa Monica, Calif., in 1956.

Before moving West to join Douglas, he was a member of the faculty of Syracuse University (he received his B.S. from Syracuse in 1952 and his M.S. from Michigan State University in 1954) and this summer will teach a course at U.C.L.A. on analysis and design of airborne pressure vessels. Mountains claim a good deal of his spare time – he skiis down them during the winter and climbs up them in the summer.

Austin Phillips (Left) and Guy V. Bennett of Douglas

More accurate tests for better motor cases is the subject of the second article, written by Guy V. Bennett, head of metallurgical research at Douglas. (He's shown in the photo above, right, with Austin Phillips of Douglas – both were authors of a May *Metal Progress* article on the electron microscope, and were written up in that issue on p. 194.)

R. E. Heise, author of the third in the series, covering advanced fabrication methods, was metals research coordinator at Douglas until recently when he left to join the aeronutronics division of Ford Motor Co. A graduate of Purdue University (1950) with a B.S. degree in metallurgical engineering, he joined Douglas in 1956 where he was responsible for research on ultra-high strength steels until 1959 and promotion to his last position.

The advantages and limitations of five types of furnaces for heat treating stainless steel tubing and wire are cited by C. H. Vaughan, assistant vice-president of the Electric Furnace Co., Salem, Ohio, in his article on p. 108, the last article in our series on "Heat Processing of Stainless Steels", which was based on the symposium sponsored by the Industrial Heating Equipment Assoc. at the National Metal Congress in Philadelphia. Mr. Vaughan began his association with Electric Furnace Co. while still a mechanical engineering student at the University of Cincinnati, working on a part-time basis. After graduation in 1934, he joined the company's engineering department and is now assistant vice-president and sales manager. He is organizing a European sales office, and will be joined there by his wife and daughter (a college sophomore).

A prominent member of the Industrial Heating Equipment Assoc., he has served on several committees and was president in 1953-54. For relaxation he handmakes articles of jewelry – cutting, polishing and mounting semiprecious stones.

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Circle 443 on Page 48-B